

Soft-Tissue Surgery of the Craniofacial Region

**Edited by
John A. Persing
Gregory R. D. Evans**

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New York London

Informa Healthcare USA, Inc.
52 Vanderbilt Avenue
New York, NY 10017

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Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-10: 0-8247-2893-9 (Hardcover)
International Standard Book Number-13: 978-0-8247-2893-9 (Hardcover)

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Library of Congress Cataloging-in-Publication Data

Soft-tissue surgery of the craniofacial region / edited by John A. Persing,
Gregory R. D. Evans.
p. ; cm.

Includes bibliographical references and index.

ISBN-13: 978-0-8247-2893-9 (hardcover : alk. paper)

ISBN-10: 0-8247-2893-9 (hardcover : alk. paper)

1. Face--Complications--Surgery. 2. Skull--Complications--Surgery.
3. Soft-tissue injuries--Surgery. 4. Surgery, Plastic. I. Persing, John A. II. Evans, Gregory R. D.
[DNLM: 1. Face--surgery. 2. Craniofacial Abnormalities--surgery. 3. Reconstructive Surgical
Procedures--methods. 4. Soft-Tissue Injuries--surgery. WE 705 S681 2007]

RD763.S6447 2007

617.5'20592--dc22

2007009804

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Preface

The concept of developing a book focussed on the analysis and surgical treatment of soft-tissue deformities of the craniofacial skeleton originated in a meeting of the American Society of Maxillofacial Surgeons. It has been long recognized that craniofacial and maxillofacial surgery, which included the management of congenital anomalies, facial bone fractures, as well as tumor involvement of the face and skull, have primarily centered around the correction of the bone abnormalities. Tremendous advances have been made, with input from abroad and the United States, including the work of Drs. Paul Tessier, Fernando Ortiz Monasterio, Daniel Marchac, Jacques Van der Meulen, Jacques Marquis Converse, Milton Edgerton, Joseph McCarthy, and others. The success of the bony work was so great, however, that it overshadowed another area of expertise in the plastic surgeons' treatment armamentarium, namely, the correction of soft-tissue anomalies of the craniofacial region.

This book is organized to highlight some areas of specific focus of plastic surgeons in this area. It is arranged so that both reconstructive and aesthetic considerations in the treatment of soft-tissue anomalies are addressed. Admittedly, virtually all soft-tissue anomalies also have a bony component to them, but, for this presentation, it is intended that the emphasis be almost solely on the treatment of soft-tissue anomalies rather than the bony abnormalities. As the reader is aware, the issue of correction of bone abnormalities has been addressed in multiple other publications in the past.

The beginning of the book describes conditions involving the scalp, followed by eyes and periorbital structures, ears, nose, midface, and then the lower face. It is clear that with the introduction of many techniques, such as tissue expansion and microvascular transfer of soft tissues, a number of major advances have been made. It is also interesting to note that use of local flap tissues, long considered the province of the plastic surgeon, is now regaining additional emphasis, particularly when used in combination with expansion techniques. Interest in reconstructive surgery for problems in the craniofacial region continues to expand to include nasal reconstruction following cancer involvement, ear reconstruction for congenital anomalies, lip reconstruction following tumor ablation, and congenital anomalies. On the other hand, more recently, due to the marriage of reconstructive techniques with aesthetic concerns, a greater sophistication of aesthetic techniques amenable to reconstructive problems and further improvement in aesthetic and reconstructive abnormality results have evolved.

In short, there is "cross talk" between reconstructive and aesthetic surgery in the management of irregularities in the face and neck, and these are highlighted individually. It is anticipated that evolution of these techniques will continue. Clearly, we have not solved all the soft-tissue anomalies in the head and neck region. In fact, we think the soft-tissue abnormalities present the greatest challenge for craniofacial plastic surgery in the future. With the development of bone remodeling techniques, both osteotomies and stabilization, reshaping, and replacement have become more predictable. What has not been as effectively corrected are the anomalies related to the soft-tissue deformities, particularly traumatic and congenital anomalies. As the face is the feature of human anatomy most emphasized in aesthetics and normal social behavior, it behooves us to identify ways in which we can improve techniques for dealing with anomalies so that the patient may have improved quality-of-life.

The intent of this book, then, is to highlight the current practices in the management of these particular areas and to subsequently spur all of us into developing improved solutions for persistent problems.

*John A. Persing
Gregory R. D. Evans*

Contents

Preface iii

Contributors vii

- 1. Introduction to Various Lasers 1**
Robyn Cohen and Seth R. Thaller
- 2. Medial and Lateral Canthal Reconstruction 7**
Kevin A. Brenner, Karen Kim, and Gregory R. D. Evans
- 3. Eyelid Reconstruction 21**
Timothy J. McCulley
- 4. Lip Reconstruction 43**
Mark A. F. Knight, Hooman Shabatian, and Gregory R. D. Evans
- 5. Scar Revision, Dermabrasion, Local Flaps 55**
Hooman Shabatian, Mark A. F. Knight, and Gregory R. D. Evans
- 6. Microsurgical Reconstruction of Craniofacial Soft-Tissue Defects 69**
Marcus Castro Ferreira, José Carlos Faria, and Julio Morais Besteiro
- 7. Hair Transplantation 77**
Jack Fisher
- 8. Forehead/Brow/Soft-Tissue Surgery for Migraines 93**
Bahman Guyuron and Lisa A. DiNardo
- 9. Management of Velopharyngeal Dysfunction 113**
Peter D. Witt
- 10. The Lacrimal Outflow System 129**
Nicholas T. Iliff
- 11. Facial Burns: Management and Reconstruction 157**
Joan L. Monaco, Mani Mani, and W. Thomas Lawrence
- 12. Cheek Reconstruction 183**
Parviz Mafi
- 13. Traumatic Tattoo 193**
Craig A. Hurst and Louis Morales
- 14. Composite Reconstruction of Midface Defects 201**
Peter C. Neligan
- 15. Blepharoplasty 211**
John A. Persing and Bianca Knoll

- 16. Cheek Reconstruction: Regional and Microvascular Free-Tissue Transfer** 223
Yoon S. Chun and Julian J. Pribaz
- 17. Facial Fractures** 241
Warren Schubert
- 18. Rhinoplasty** 257
Jeffrey E. Janis and Rod J. Rohrich
- 19. Imaging of Soft-Tissue Defects** 291
Joseph M. Rosen, David S. Sargent, and Julie S. Young
- 20. Managing the Cleft Nasal Deformity: Controversies in Correction** 301
John A. van Aalst and A. Michael Sadove
- 21. Skin Care (Peels, etc.)** 313
Viktoriya Bul, Malcolm D. Paul, and Rostislav Bul
- 22. The Subperiosteal Facelift** 321
Oscar M. Ramirez and Charles R. Volpe
- 23. Cleft Palate** 337
Keith A. Hurvitz and Michael J. Sundine
- 24. Aplasia Cutis Congenita** 345
Moises Salama, Latanya T. Benjamin, Seth R. Thaller, and Lawrence A. Schachner
- 25. Mentoplasty** 351
Barry L. Eppley
- 26. Facial Paralysis** 359
Gregory H. Borschel and Ronald M. Zuker

Index 375

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1 Introduction to Various Lasers

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BASIC PRINCIPLES AND THERAPEUTIC USES (INCLUDING SIDE EFFECTS)

Laser, which is an acronym for light amplification by stimulated emission, was first developed in 1959. However, Einstein, in 1927, is credited with initially proposing the concept. In 1963, the prototype ruby laser was used in the treatment of human skin by dermatologist Leon Goldman (1).

A combination of complex laser-tissue interactions and the unique properties inherent in laser light account for the therapeutic actions of laser energy. Laser light consists of four therapeutic physical properties: wavelength/monochromaticity, collimation, coherence, and compressibility. The laser medium in the optical cavity through which the light must pass determines the specific single, discrete wavelength of that laser. Cutaneous targets such as hemoglobin, water, melanin, or tattoo ink each preferentially absorb different wavelengths of light (2). Monochromaticity is defined as the selective ability to target chromophores based on their individual absorption spectrum and therefore targets certain tissues (1). Collimation, a second property of lasers, achieves propagation of light across long distances without divergence (2) or diminished intensity (1). This allows the laser to focus on specific small locations (2) over a long distance (1), which it accomplishes by emitting a narrow intense beam of light in a parallel fashion. Collimation ensures both the accuracy of the laser and precise tissue destruction. A third property of lasers, known as coherence, means that the laser light travels in phase with both time and space (2). Coherence is characterized by light waves that are aligned properly. This permits a high intensity of light that can be focused directly over a small area without aberrant waves, resulting in minimal thermal damage to the adjacent areas. The fourth property of lasers is called compressibility. It is characterized by the use of ultra short pulses of energy, which aid in focusing laser energy to the potential target (1).

Anderson and Parrish's theory of selective thermolysis explains the potential to selectively destruct targeted tissues without causing significant thermal damage to adjacent normal tissues. This can be accomplished by choosing a wavelength that will be absorbed by the target tissue and its chromophores but not the adjacent tissues. Selective thermolysis theory also provides an explanation for the protection of the normal tissue, which is accomplished by choosing appropriate pulse duration for exposing the tissue to light. Therefore, this must be shorter than the required period immediately after laser irradiation for the tissue to cool to one half of its peak temperature. This is also known as the thermal relaxation time. The second requirement is the laser's energy density, known as fluence, which can be sufficiently delivered to destroy the target tissue within the allotted time parameters. In summary, Anderson and Parrish's theory demonstrates that by manipulating the wavelength, pulse duration, and fluence of the laser, it is possible to create a laser therapy specific for various cutaneous applications, with maximal target destruction and minimal thermal damage to surrounding normal skin (2).

Whenever a laser is applied to the skin surface, the light can either be absorbed, reflected, transmitted, or scattered. Fortunately, only absorbed light has a clinical effect, as demonstrated by the first law of photobiology. Absorption of light is referred to as the energy density or fluence and is measured in joules per square centimeter (J/cm^2). Chromophores present in a tissue determine which wavelengths will eventually be absorbed as well as the amount of absorption. Once absorbed by the skin, laser energy effect may be either photomechanical, photothermal, or photochemical. Photomechanical effect occurs when rapid thermal expansion creates acoustic waves that subsequently destroy the tissue absorbed by the laser energy.

This is one of the most frequent effects observed in the practical practice of cutaneous laser surgery. Photothermal effect occurs when the absorbed laser energy is converted into heat, subsequently destroying the target tissue. Currently, this is also a common method employed in cutaneous laser surgery today. Finally, photochemical effect consists of native or photosensitizer-related reactions that result in photodynamic therapy. This effect is less frequently recognized in cutaneous laser surgeries (2).

Laser penetration is determined by a combination of both absorption and scattering. Minimal light scattering occurs in the epidermis because of the lack of collagen in this layer; however, in the dermis, where collagen fibers are more numerous, there is a much greater amount of light scatter. The amount of scattering increases as the wavelength decreases and vice versa. Therefore, the amount of penetration increases at the same time as the wavelength increases. This remains constant until the midinfrared region of the electromagnetic spectrum, when further increases in wavelength no longer result in more penetration. While the mid- to upper-infrared range of the electromagnetic spectrum, there is superficial penetration due to the great absorption of these wavelengths by tissue water. This is the most abundant chromophore in these superficial tissues and the basis of ablative skin resurfacing. This results from selective vaporization of water containing tissues thus destroying the superficial tissues and allowing new tissue layers to reach the skin surface (2).

Today, many options are available in cutaneous laser surgery. Continuous wave (CW) lasers, such as argon and CO₂, emit long-duration, constant-beam light. On the downside, these lasers lack the precision of other lasers, and often result in injury to surrounding normal tissues. Potassium-titanyl-phosphate (KTP), copper vapor, copper bromide, krypton, and argon-pumped tunable dye lasers are examples of quasi-CW mode lasers, which release the CW laser in ultra short bursts, therefore, giving an intermittent emission of the constant laser energy. These pulsed laser systems consist of ultra short pulses with intervening times of 0.1–1 second between pulses. Pulses are either long-pulsed (pulse duration 450 microseconds to 40 milliseconds) or very short-pulsed (5–100 nanoseconds). CO₂ lasers are “superpulsed,” meaning that they produce a repetitive pattern of very short pulses in order to minimize thermal damage to surrounding normal tissue. Due to the very short thermal relaxation times of most cutaneous chromophores, the pulsed and quasi-CW systems are better adapted for cutaneous laser surgery than CW lasers based on Anderson and Parrish’s theory of selective thermolysis (2).

Presently, lasers are utilized in a variety of medical specialties for multiple medical and cosmetic applications including rosacea, solar lentigines, seborrheic keratoses, arteriovenous malformations, vascular malformations, capillary hemangiomas, acne, keloids, nevi (congenital, dysplastic, epidermal), psoriasis, vitiligo, warts, facial hair removal, pigmented lesions, wrinkles, telangiectasias, spider veins, varicose veins, scars, tattoo removal, and melasma. This chapter reviews various available lasers as well as the numerous medical and cosmetic conditions that are amenable to treatment.

Q-SWITCHED RUBY LASERS

The ruby laser is clinically shown to effectively treat dermal pigmentation without causing residual scarring because when its 694 nm wavelength is delivered in 20 to 40 nanosecond pulse durations, it is preferentially absorbed by melanin. In addition, the long wavelength of this laser allows dermal penetration. For this reason, it is also an excellent treatment tool for nevus of Ota (5 to 6 J/cm², four to six treatments) and other deep-pigmented lesions. In current laser surgery techniques, the tissue heating and destructive effects of the ruby laser are improved by using the quality or “Q”-switching technique, which raises energy densities up to 10 J/cm². When exposed to the ruby laser, the skin often whitens for up to 30 minutes. The skin becomes swollen and erythematous for the following 30 to 60 minutes, with subsequent cutaneous vesiculation lasting for 24 to 36 hours, and complete healing by post-treatment day 10 to 14 (1).

Common applications include treatment of ephelides, blue nevi, melanocytic nevi, Peutz-Jeghers associated lentigos, isolated labial lentigos, solar lentigines (5 to 6 J/cm², one to two treatments), removal of tattoos, and hair removal. The Q-switching technique produces lasers with high energy, ultra-short bursts that destroy tattoo ink particles without injury to the surrounding skin. Phagocytosis, lymphatic transportation, and transepidermal excursion of

these destroyed ink particles follow completing the process. This is more effective in treating amateur tattoos than professional tattoos because the former do not penetrate the skin as deeply, and generally use simpler, less densely packed dyes. Therefore, professional tattoos can be removed in eight visits whereas amateur tattoos may take only four to six visits. Complications of Q-switched laser tattoo removal include hypopigmentation. This occurs because these lasers target tattoo ink as well as melanin. Other potential complications consist of anaphylaxis due to the high antigenicity of the destroyed material, extracellular ink particles, and/or paradoxical tattoo ink darkening (1).

Café-au-lait lesions (5 to 6 J/cm², three to four treatments), nevus spilus, and Becker's nevus may also be treated with the ruby lasers; however, the recurrence rate remains very high, generally within the first six to 12 months post-treatment. The Q-switched ruby, as well as other pigment specific lasers, has been used successfully to treat infraorbital dark circles; however melasma and postinflammatory hyperpigmentation do not usually respond effectively to the ruby lasers (1).

Ruby laser complications include transient hyperpigmentation in 15% of patients, temporary hypopigmentation lasting for approximately two to six months, and, rarely, permanent depigmentation, scarring, or epidermal atrophy, which occur in less than 5% of treated patients (1).

Q-SWITCHED ALEXANDRITE LASERS

The Q-switched alexandrite lasers emit light at 755 nm wavelength at a pulse duration of 50 to 100 nanoseconds. This and the ruby laser have similar wavelengths, penetrations, and Q-switching techniques. For this reason, it is highly specific for melanosomes and therefore is used in the management of dermal and epidermal hyperpigmentation. Other common uses include treatment of benign melanocytic nevi, nevus of Ota, solar lentiges, removal of dark (blue-black) tattoos by a mechanism similar to the Q-switched ruby laser, and hair removal. As with ruby lasers café-au-lait spots tend to recur after treatment with the Q-switched alexandrite laser (1).

Treatment sessions with the Q-switched alexandrite laser begin at 6 to 6.5 J/cm² over a 3 mm target. Treatment sessions should be preformed every six to eight weeks to permit adequate tissue healing. Transient hypopigmentation after alexandrite laser treatment may occur, but is much less common than with ruby laser treatment (1).

Q-SWITCHED NEODYMIUM:YTTRIUM-ALUMINUM-GARNET LASERS

Neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers generally emit a wavelength of 1064 nm and have a pulse duration of 10 nanoseconds. At this wavelength, the Nd:YAG laser targets dermal pigmented lesions such as melanocytic nevi, the nevus of Ota, dark tattoos, and also may be employed in the removal of unwanted hair. Frequency can be doubled, which reduces the wavelength to 532 nm and allows more specific treatment of epidermal pigmented lesions, such as café-au-lait macules and lentigines, and removal of blue-black or red tattoos by a mechanism similar to the other Q-switched lasers. Nd:YAG is the standard for removal of red tattoo ink (1).

Laser therapy is usually delivered over two to five treatments of 8 J/cm² with a 3 mm spot size to achieve optimal results. Side effects include hyperpigmentation, hypopigmentation, and transient cutaneous texture changes. The latter is encountered more often at the higher fluences (1).

PULSED DYE LASERS

Pulsed dye lasers have multiple subtypes, including pigmented and flashlamp. Pigmented lesion pulsed dye laser emits 510 nm light at a 300 nanosecond pulse duration. This wavelength and pulse duration are effective in the treatment of epidermal pigmented lesions such as solar lentigos and café-au-lait spots. Solar lentigos usually clear after one to two treatments at 2.5 J/cm², café-au-lait spots on the other hand generally require six to eight treatments of 2.5 to 3.5 J/cm² at eight week intervals. Fifteen percent of patients treated for café-au-lait spots experience transient pigmentary changes (1).

Flashlamp-pumped pulsed dye laser achieves vascular specificity by using a 585 nm wavelength, but there is less energy delivery to the deeply pigmented tissues. This occurs because epidermal melanin interferes with 585 nm pulsed dye laser pulses without absorbing them, resulting in less hypopigmentation at this wavelength. The primary reason that the flashlamp-pumped pulsed dye laser was developed was for the treatment of port wine stains (6 to 7 J/cm², spot size 5–7 mm). This laser is now the standard of care in the treatment of spider angiomas, pyogenic granulomas, telangiectasias, and superficial hemangiomas (1).

Flashlamp-pumped pulsed dye laser treatment fluences range from 4 to 9 J/cm² with spot sizes ranging from 5 to 10 mm. Deeper tissue penetration is achieved as the spot size increases, requiring increased fluence to gain the same clinical result.

Complications of pulsed dye lasers include purpuric macules that immediately follow the treatment and usually resolve within one to two weeks, crusting of skin (4%), and/or scaling of skin (12%). Rare complications occur in less than 1% of patients. These include cutaneous blistering and scarring that usually occur with delivery of excess heat energy (1).

Other applications for the pulsed dye laser when used at 585 nm include removal of red tattoos, warts, early erythematous striae atrophicae (over several sessions), and hypertrophic scars and keloids. This laser, as well as other pulsed dye 585 nm vascular specific lasers, targets the erythematous component of hypertrophic scars and keloids. It has been shown that, as a result of the destruction of the entrapped capillaries in these abnormally proliferative scars, there is a decrease in scar pliability, texture, thickness, and associated symptoms. Pathologic specimens of the postirradiated scars also show a decrease in mast cell number, with an increase in collagen turnover and decreased collagen deposition (1).

ARGON-PUMPED TUNABLE DYE LASERS

This is a quasi-CW because, unlike the older technology CW argon laser, this laser can pulse its light beam using a robotized scanner device. Quasi-CW lasers are preferable in patients with focal vascular lesions, especially in areas such as the face. Although these lasers have less vascular specificity there is less risk of complications such as postirradiation purpura (1).

The argon-pumped tunable dye laser emits 577 or 585 nm wavelengths to treat vascular lesions using a 0.1 mm spot size to trace each blood vessel. Specific uses of the argon-pumped tunable dye laser include telangiectasias and less frequently port wine stains (1).

Verrucae can also be successfully treated by laser destruction of the supporting vasculature with an argon-pumped tunable dye laser or any other 585 nm vascular specific pumped lasers (1).

COPPER VAPOR LASERS

Copper vapor laser can be emitted at either 510 or 578 nm in 20 nanosecond pulses separated by 67 microsecond intervals. This is classified as a quasi-CW system because the pulses are emitted at a repetition rate of 1500 pulses per second. This means that this laser may cause some nonspecific thermal damages in tissues adjacent to the target tissue and/or result in a higher risk of cutaneous pigmentary and textural changes.

At 578 nm, this is used as a vascular laser; however at 510 nm it becomes a pigment laser and can be used to remove café-au-lait macules, lentigines, and dermatosis papulosa nigra (1).

At 578 nm, wavelength the copper vapor laser is used to treat facial telangiectasias. Results are comparable to those seen with the argon-pumped tunable dye laser. Copper vapor laser follows along the path of blood vessels using a 150 micrometer spot to minimize blanching. Treatments are delivered twice a month until complete resolution is achieved. Immediately following the treatment some mild swelling and/or crusting occur, usually resolving within one week (1).

KTP LASERS

Although KTP lasers have less vascular specificity, when emitted as a 532 nm wavelength light beam with millisecond pulses, they may be successfully employed in the treatment of

telangiectasis. This quasi-CW laser is similar to the argon-pumped tunable dye laser in its treatment of focal telangiectasis with minimal postirradiation purpura. KTP laser is delivered at 15 to 20 J/cm² with millisecond pulses over one to three sessions (1).

KRYPTON LASERS

Krypton lasers are delivered at 568 nm wavelength using 0.7 to 0.9 W power and a 0.1 mm spot with a 0.2 second pulse to treat vascular lesions. Mild cutaneous erythema and edema may result from these treatments similar to every other quasi-CW laser systems (1).

CARBON DIOXIDE LASERS

This is an older laser system originally used to remove tattoos. Often treatment resulted in scarring of surrounding normal skin secondary to excessive associated thermal injury (1). Hypertrophic scars and keloids had been treated with carbon dioxide lasers. Recurrences commonly occurred in the first two years post-treatment; now this treatment option has been replaced with vascular specific 585 nm pulsed dye lasers that specifically target the erythematous component of the hypertrophic scars or keloids (1).

Epidermal or keratotic and dermal or papular lesions such as epidermal nevi, verruca vulgaris, actinic chelitis, and seborrheic keratoses can also be treated with CW carbon dioxide lasers. Trichoepitheliomas, sebaceous hyperplasia, xanthelasma, and syringomas are also very responsive to treatment with carbon dioxide laser vaporization (1).

Finally high-energy pulsed carbon dioxide lasers also known as “superpulsed” carbon dioxide lasers may be used for skin resurfacing at 10,600 nm. This avoids the undesirable complications of CW carbon dioxide lasers such as nontarget tissue thermal damage, with subsequent scarring and hypopigmentation. Superpulsed techniques use high energy short pulses to deliver 500 mJ of energy per pulse, allowing rapid vaporization of unwanted tissues without transmission of heat to adjacent normal tissue. Therefore, this is very effective at resurfacing skin along with rhytides and/or atrophic scars. It has been reported that these lasers are used to reduce intraoperative bleeding and postoperative recovery time when used in conjunction with blepharoplasties, facelifts, and hair transplantation (1).

Resurfacing lasers have also been used to treat infraorbital dark circles with good results (1). Complications include erythema that may last two to four months (1).

ERBIUM:YTTTRIUM-ALUMINUM-GARNET LASERS

Erbium:YAG lasers are pulsed 2940 nm lasers are often used in skin resurfacing, since it has been reported that they create less residual thermal damage. Therefore, there is reduced post-treatment erythema compared to carbon dioxide lasers. However, the limited thermal effect and decreased collagen contraction of this laser seem to make it less effective for skin resurfacing (1).

ARGON LASERS

CW lasers that are older technology have now been replaced by the more specific argon-pumped tunable dye laser. In the past, this laser was used in the management of hypertrophic scars and keloids. Common recurrences have been reported in the first two years. Therefore, this technique has now been replaced with vascular specific 585 nm pulsed dye lasers that target the erythematous component of the hypertrophic scars and keloids (1).

Currently, many laser options are available to treat a wide variety of medical and cosmetic dermatologic conditions. Therapeutic options will continue to expand with advancing laser technology resulting in improved clinical results and fewer associated untoward sequela.

2 Medial and Lateral Canthal Reconstruction

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BACKGROUND

As the incidence of periorbital and midface surgery has increased, so too has the need for canthal reconstruction. In 1952, Converse and Smith (1) first described medial canthoplasty for correction of canthal malposition in patients with complicated naso-orbito-ethmoid (NOE) fractures and medial orbital wall fracture malunion following midfacial trauma. Since that time, numerous authors have described techniques for both canthoplasty and canthopexy as integral components of periobital rejuvenation and canthal reconstruction (1–48). Each technique has evolved to specifically address a variety of upper and lower eyelid pathology including malposition, laxity, ectropion, entropion, soft-tissue trauma, and underlying skeletal deformity. Reconstruction of the lateral canthal angle now plays an important role in rejuvenation of the aging midface, and becomes even more critical during secondary blepharoplasty, when initial attempts at lateral canthal stabilization have failed. Reconstruction of the medial canthus, while of less importance during facial rejuvenation, often requires skilled repair following trauma, cancer ablation, and certain congenital deformities.

ANATOMY OF THE LATERAL AND MEDIAL CANTHI

The canthal tendons are fibrous extensions of the tarsus that directly suspend the tarsal plates of both the upper and lower eyelids from the bony medial and lateral orbital rims (3,34–37,42). Located deep to the skin and orbicularis muscle fibers, the tendinous extensions of the upper lid join together with those of the lower lid to form the lateral canthal tendon (LCT), laterally and the medial canthal tendon (MCT) medially (12,37,42). In this manner, they form two tarso-ligamentous slings that maintain both eyelids in apposition against the globe. The lateral tendon inserts into the lateral orbital tubercle (Whitnall's tubercle), located on the inner aspect of the lateral orbital wall, 2 to 3 mm posterior to anterior edge of the rim. The medial tendon inserts into the lacrimal crest of the lacrimal bone approximately 1.5 to 2 mm caudal to the lateral canthus in the axial plane. At the lateral orbital tubercle, the lateral horn of the levator aponeurosis, Lockwood's inferior suspensory ligament, and the check ligament of the lateral rectus muscle all join the LCT to form the lateral retinaculum.

The MCT is a stronger tripartite ligament that provides a hinge for the eyelids and maintains the normal angular palpebral fissure (3,31,42,44). The anterior limb is attached to the anterior lacrimal crest and continues toward the nasal bone periosteum. The superior limb is fixed to the medial orbital rim several millimeters above. The posterior limb attaches to the posterior lacrimal crest. The anterior and posterior limbs of the MCT envelope the lacrimal sac, functioning as a pump in the lacrimal drainage system. Tears drain into the lacrimal sac through the superior and inferior puncta, which open 5 to 7 mm lateral to the canthal angle (3).

RECONSTRUCTIVE TECHNIQUES FOR THE LATERAL CANTHUS

Several congenital, post-traumatic, and acquired pathologic conditions can result in loss of lateral canthal support. However, canthal laxity is more commonly seen as a sequela of facial aging or following inadequate canthal support procedures (2–14,33,36–38). Periorbital rejuvenation is critical to maintaining a clean continuum, as the upper lid blends into the brow and forehead superiorly, and the lower lid forms the lid-cheek junction inferiorly (2,3,33,36–38). Other indications for lateral canthoplasty include horizontal eyelid laxity, entropion, ectropion, lid retraction, and canthal dystopia (2–14,33). During trilateral total eyelid reconstruction,

lateral canthal anchoring becomes critical for lower lid support. A surgeons' choice of technique should be individualized for every patient and will depend not only on the particular indication, but also on their own training, experience, and comfort level with a given technique. Thorough preoperative analysis can help to minimize common postoperative complications which include lower lid malposition, rounding of the lateral canthal angle, lagophthalmos, bowstringing, globe-lid dysfunction, canthal dystonia, and chronic inflammation (1–14,33). Deciding between canthopexy and canthoplasty procedures is a complex process. Preoperative considerations include knowledge of previous procedures performed, degree of lower lid laxity on “snap” testing, vector analysis with exophthalmometry, and finally, the relationship of the lateral canthus to the medial canthus in the axial plane (2,3).

Dermal Orbicular Pennant

Indications

Dermal orbicular pennant support is indicated in patients with lower lid malposition secondary to lower lid laxity, and more rarely, for paralysis (2,5,7,39,40). In such cases, weakening and medial migration of the lateral canthus create a shortened horizontal aperture, a round lateral canthal angle, and an overall “old” appearance to the eye shape (7). This procedure is particularly useful in individuals with lateral canthal dystopia, where a disparity greater than one centimeter exists between the lateral orbital rim and the external commissure. Restoring lid posture with horizontal shortening techniques alone can be difficult in dystopic patients (8).

Technique

Extending laterally from the lateral canthus, an elliptical flap is outlined which measures 1 cm in horizontal diameter, and 0.5 cm in vertical width (7). The flap is carefully de-epithelialized, and incised down through the underlying dermis and orbicularis muscle. The flap is dissected medially to expose the LCT, so that the lower limb of the tendon is included with the flap. The lateral retinaculum is incised in part or in total, releasing it from the orbital rim (Fig. 1). The dermal pennant is sutured to the periosteum inside the lateral orbital rim at the level of the upper border of the pupil with the patient in primary gaze. Adjustments are made for lower eyelid elevation and angulation. Slight overcorrection is desirable so that the lower eyelid covers the inferior cornea by 1 to 2 mm. The skin is then closed.

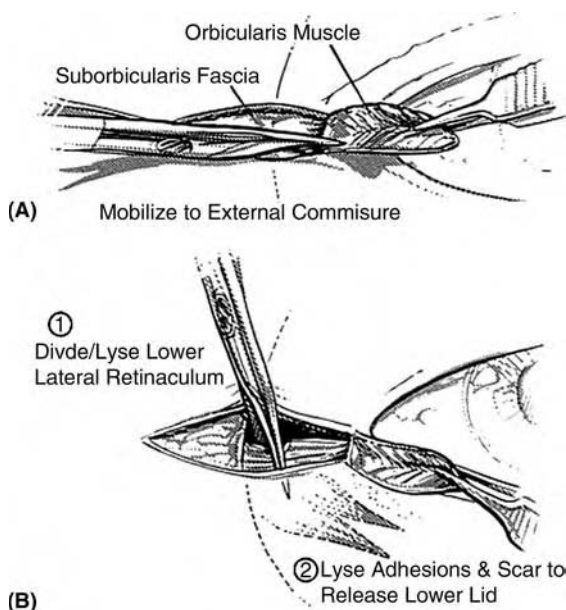


FIGURE 1 (A) The inferior border of the dermal-orbicular pennant is elevated with scissors to the external commissure, which remains intact. (B) The inferior aspect of the lateral retinaculum is divided. The scissors are then placed along the orbicularis muscle where they are utilized to release adhesions and scarring, resulting in a freely mobile lateral lower lid.

Strengths

This technique preserves the lateral canthal angle including the palpebral and bulbar conjunctiva (2,5,7). Direct injury to the lateral rectus muscle or globe is infrequent. Diplopia secondary to cicatricial restriction of the lateral rectus muscle function is likewise minimized. A natural appearing and aesthetically pleasing aperture results because the external commissure is not surgically divided (8). Since the surgical planes and structures are easily identifiable, this procedure is technically simple to perform. Finally, vertical cartilage spacer grafts are easily incorporated when necessary.

Weaknesses

Removal of excess skin of both upper and lower eyelids may result in lagophthalmos (7). Raising the dermal pennant disrupts tissue lateral to the lateral canthus, potentially endangering the lymphatic drainage of the upper and lower eyelids (2,7). An additional concern is the temporal branch of the facial nerve, which lies in close proximity. The procedure can also weaken the orbicularis muscle fibers, causing paralysis, malalignment of the upper and lower eyelids, and problems with tear flow dynamics (2). The positioning of the fixation suture at the level of the upper border of the pupil varies with a dynamic pupil diameter, thus making its use as a reference point hazardous. Overcorrecting the position of the lateral canthus by placing it superior to its ideal position is fraught with potential complications, such as unpredictable downward migration of the lateral angles, suboptimal functioning of the eyelids, and rounding of the lateral canthal angle (2).

Inferior Retinacular Lateral Canthoplasty**Indications**

Inferior retinacular lateral canthoplasty was developed primarily for cosmetic blepharoplasty in patients requiring lower lid tightening. When used in patients with a negative vector and lower lid laxity (as seen with hyperthyroidism or severe myopia) it minimizes the need for skin removal and decreases the risk for inferior scleral show, lateral canthal rounding, and ectropion (2,6,8). In older patients, the technique works to counteract decreased lower lid tonicity. It minimizes deformities of the lower eyelid and lateral canthus that are more frequently associated with the lateral tarsal strip and dermal orbicular pennant lateral canthoplasty (6,8). It is also useful for correcting acquired lateral canthal deformities and postblepharoplasty lower eyelid malposition (6).

Technique

Through the lateral aspect of an upper eyelid blepharoplasty incision, a skin-muscle flap is raised along the lateral orbit and inferior rim to expose the LCT. Superior to the lateral fat pad, the inferior portion of the lateral retinaculum is identified and dissected free from the lateral orbital rim. The cut margin of the freed lower eyelid is secured with a double-armed 4-0 Polydek suture and then fixed inside the lateral orbital rim at a level corresponding to the superior border of the pupil with the globe in primary gaze (Fig. 2). The result is overcorrection, with the lower eyelid covering the inferior cornea by 1 to 2 mm. The skin is then closed.

Strengths

Open visualization of all canthal structures makes the inferior lateral retinacular canthoplasty procedure technically simple to perform, easily enabling preservation of the lateral canthal angle (2,5–7). The lateral palpebral commissure is not divided which minimizes the risk of lower lid and commissural deformity. Additionally, lack of an incision between the upper and lower lids significantly reduces the degree of postoperative lymphedema or orbicularis palsy. This canthoplasty can be performed concurrent to upper blepharoplasty, utilizing the same incision.

Weaknesses

Surgical overcorrection changes the horizontal dynamic position of the lateral canthus and may result in asymmetric relaxation and unequal lid position. It may also shorten the vertical palpebral fissure. Override of the lower over the upper eyelid, as well as distortion of the upper eyelid fold, can both occur from passing the inferior lateral retinaculum superficial to the

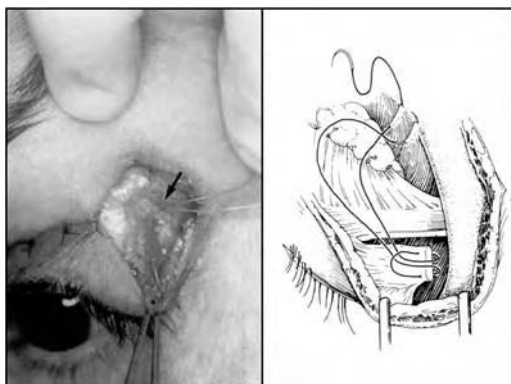


FIGURE 2 Fixation of the eyelid to the lateral orbital rim.

superior retinaculum prior to suspension to the orbit. Rarely, granulomatous foreign body reaction may occur around any suture, which inadvertently passes through the conjunctiva. Lacrimal and epithelial lined cysts may also result.

Transpalpebral Lateral Retinacular Suspension

Indications

Transpalpebral lateral retinacular suspension is indicated when mild lower eyelid laxity or malposition exists concomitantly with herniated lower eyelid orbital fat (2,5). The procedure is useful when resection of a significant amount of lower eyelid skin is anticipated or when a previous horizontal shortening procedure removed excess lid length but failed to restore the lateral canthal angle.

Technique

The lateral aspect of an upper eyelid blepharoplasty incision is used for initial exposure. An additional incision is made inferior to the LCT (Fig. 3). Both arms of a double-armed 5-0 polypropylene suture are passed from the inferior incision superiorly and laterally through the lateral retinaculum, and out the upper blepharoplasty incision. The sutures are fixed to the periosteum inside the lateral orbital rim (Whitnall's tubercle) at the level of the upper border of the pupil. If the periosteum is deficient, two holes can be drilled into the lateral orbital rim to allow secure suture suspension. This secures and elevates the lateral canthus. The skin incisions are then closed.

Strengths

The greatest advantage of this technique is the minimally invasive alteration of the contour, shape, and height of the lateral canthus (2). It requires no additional dissection through the upper eyelid to expose the lateral retinaculum and it allows for precise placement of the lateral canthus at a desired location. Recreation of the lateral retinaculum and lateral canthal angle can be avoided because there is no need for canthal reformation. This significantly reduces operative time and minimizes postoperative discomfort (2,5). Ultimately, an enhanced lateral brow is more pleasing (5).

Weaknesses

Postoperatively, the lateral canthal angle may migrate toward its preoperative position (2,5). Dissatisfaction with appearance, and difficulty with eyelid closure have both been observed in a significant number of patients who experience persistent overcorrection of the lateral canthus position (2).

Lateral Tarsal Strip

Indications

The lateral tarsal strip is the canthoplasty of choice for paralytic, cicatricial, and mechanical ectropion as well as for postblepharoplasty lower eyelid malposition (4,6,8,10). It is ideal for

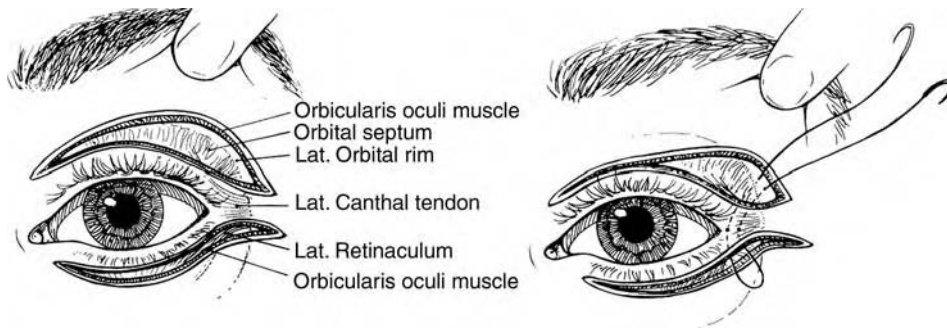


FIGURE 3 Exposure for canthal reconstruction. *Abbreviation:* Lat, lateral.

those with moderate to marked eyelid laxity and excess skin (3). However, it is not recommended in the exophthalmic eye (significant negative vector), in patients with high axial myopia, significant malar hypoplasia, or a horizontally deficient lower eyelid (5).

Technique

Access for the lateral tarsal strip is achieved by using a lateral canthotomy and inferior cantholysis (2,10,11,33). Following the canthotomy, the attachments of the superior and inferior canthal tendon crura are released from the lateral orbital rim. Scissor dissection then separates the anterior and posterior lamellae. The inferior border of the tarsus is released from its underlying attachments to the conjunctiva, lower lid retractors, and orbital septum. Two to three millimeters of the mucocutaneous portion of the lid margin (from the area of tarsal strip) is excised. Depending on the amount of excess skin, partial excision of the anterior lamella may be performed at this stage (11). The cut margin of the tarsal strip is then grasped and drawn laterally toward its normal anatomic insertion. The final fixation position of the lower eyelid margin is where the eyelid border reaches the inferior corneal limbus. A double-armed 5-0 permanent suture is passed from posterior to anterior through the cut edge of the tarsal strip and then sewn to the periosteum along the inside aspect of the lateral orbital rim, superior to the LCT insertion. The lateral canthal angle is reformed with a 6-0 gut suture. This suture is temporarily set aside while the double-armed suture is drawn laterally, ascertaining that the lower eyelid margin meets the limbus (Fig. 4). At this position, the suture is tied permanently. The suture for the lateral canthal angle is then tied permanently, and the skin is closed.

Strengths

The lateral tarsal strip is preferred over noncanthal eyelid resections when the laxity of the lower eyelid is thought to occur at the LCT (5). Jordan and Anderson (11) favor this procedure for many reasons. The operation directly repairs the anatomic defect, reduces the incidence of postoperative lid notching (by eliminating the use of marginal lid sutures), and simultaneously shortens the lid and corrects any canthal malposition. The procedure also preserves the youthful almond-shaped canthal angle, reduces the recurrence of canthal tendon laxity, and can be used in lieu of synthetic devices in the management of facial palsy. When performed accurately, the lower eyelid is restored to its normal anatomic position, which facilitates healing and maximizes function (2).

Weaknesses

The lateral tarsal strip procedure is technically difficult, requiring both correct anatomic positioning of the lower eyelid and precise canthal angle reconstruction (2,5,7). Shortening of the palpebral fissure can adversely affect lateral canthal dynamics (ductions and versions) as ultimate function depends on the horizontal length of the aperture. In patients with a negative vector or loss of static eyelid function, lid shortening can result in clotheslining of the lid on the

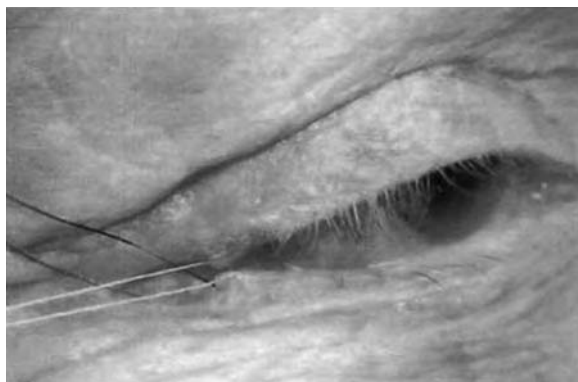


FIGURE 4 Lateral canthal angle reformation ensures proper anterior-posterior alignment of the lower and upper eyelids.

globe. Soft-tissue dissection lateral to the canthus can exacerbate postoperative lymphedema. Finally, caution must be used during anterior lamellar shortening since overresection will create excessive tension, resulting in unnatural rounding of the canthal angle (8).

Lateral Canthopexy

Indications

Lateral canthopexy is most commonly employed for treatment of mild lower lid laxity and for primary lid support during routine blepharoplasty to prevent *mild* postoperative lower eyelid malposition (12). Canthopexy is also useful in patients who suffer canthal tendon lacerations, traumatic canthal dislocations, or lateral canthal displacement from periorbital tumors and vascular malformations (4). A traditional canthopexy should be avoided in patients with preexisting vertical shortening of the lower eyelid, and may be impossible in cases of congenital tissue deficiency (14).

Technique

A double-armed 4-0 suture is used to secure the conjoined tendon of the upper and lower eyelids. The suture is then passed through the periosteum at least 4 mm inside the lateral orbital rim. The suture is tied externally on the lateral orbital rim periosteum, 3 to 4 mm from the rim's edge (3). Knize (12) reported a different type of canthopexy that utilizes the superficial lateral canthal tendon (s-LCT), a strip of the septum orbitale that connects the lateral canthus to the orbital rim at a level superficial to the LCT. The s-LCT can be transected through a temporal scalp incision or through an upper blepharoplasty incision. When access is via a temporal approach, scissors are passed between the superficial and deep temporal fascial planes. Dissection continues until the scissor tip rests under the lateral aspect of the septum orbitale, lateral to the orbital rim, and the lateral canthus. The overlying septum is then divided from deep to superficial and the medial end of the s-LCT is pulled cephalad to raise the lateral canthus. When access is via an upper blepharoplasty incision, a hemostat is used to grasp the lateral edge of the plane of the septum orbitale, which is then dissected free from the lateral orbital rim. A suture is placed into the s-LCT while a hemostat stabilizes it. If local tissue is unavailable for suturing, a secure canthopexy may require drilling anchoring holes in the lateral orbital wall (Fig. 5) (3,4).

Strengths

Lateral canthopexy is a less invasive procedure that provides lateral canthal support without altering the LCT. Such support confers protection against lower eyelid retraction or ectropion when performing a lower blepharoplasty in patients with *mild* eyelid laxity (minimal distensibility and firm snap back testing) (3,12,33). Jacobs (13) has noted other advantages including, maintenance of good eyelid position and a natural shaped aperture in younger patients, improvement of senile tendon weakness, and ability to excise more skin than is feasible without tendon fixation.

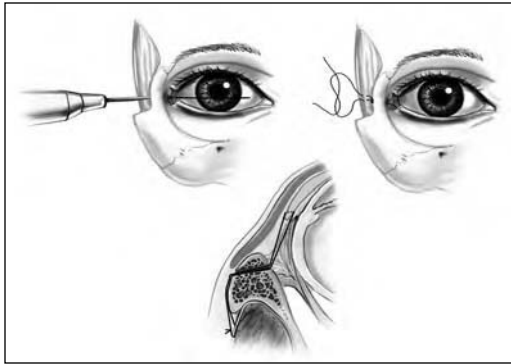


FIGURE 5 Lateral canthal tendon is secured to the lateral orbital wall.

Weaknesses

Older patients with significant horizontal laxity and a deep set globe often encounter lower lid buckling and malposition if horizontal laxity is not corrected (3,33). Orbicularis muscle function can be permanently diminished if facial nerve fibers are damaged during multiple revisions (14). Vertical dystopia can occur, resulting in an unnatural shape if the canthus is placed at an incorrect level (12). Overelevation of the lateral canthus may also occur.

RECONSTRUCTIVE TECHNIQUES FOR THE MEDIAL CANTHUS

Trauma, cancer ablation, craniofacial exposure, congenital malposition, or age-related change can all result in medial canthal defects (15–32,37). The complex anatomy of the medial canthus makes reconstruction of this area extraordinarily challenging. The medial canthal system comprises bony attachments of the tripartite MCT, neurovascular structures, and the lacrimal system. The normal anatomical concavity and multiple important surrounding structures leave very little local tissue available for reconstruction (1,16–19,23,37). The goals of medial canthal reconstruction include restoration of normal anatomy, maintenance of globe protection, and preservation or re-establishment of lacrimal drainage. Silicone Jones tubes can stent the canalicular system to help minimize lacrimal dysfunction. Traditional medial canthal soft tissue reconstruction techniques include skin grafts, V-Y advancement flaps, medial canthopexy, and glabellar and laterally based upper lid, and cheek flaps (26–28). Upper eyelid myocutaneous flaps can also be used with good long-term results (29,30). Of course, bone and canthal reconstruction must precede soft-tissue coverage in appropriate cases.

Healing by Secondary Intention

Indications

Healing of soft-tissue defects by secondary intention is often a safe, effective, and inexpensive alternative to primary reconstruction following excision of tumors surrounding the medial canthus (15,16,19). Good candidates for this approach are elderly patients with loose skin who have wounds on concave surfaces of the nose, eye, ear, and temple, as well as patients with wound diameters less than 15 mm that spare the upper or lower lid (16–20,29). Since scars in this region tend to become hypopigmented as they mature, patients with light-colored skin and patients with irregular skin pigmentation (from solar damage) will usually develop well-camouflaged scars in this area (16,18,19). This approach is useful in medically debilitated patients who may not tolerate longer reconstructive procedures, as well as following radiotherapy when the surrounding skin is unsuitable for flaps (15,16). If the MCT has been sacrificed, the conjunctiva and tarsal plate can be sutured to the anterior lacrimal crest to recreate the medial fornix, before secondary healing is pursued (29,42).

Technique

Immediately following excision of the periocular skin tumor, the wound is dressed with a nonadherent absorptive dressing (paraffin gauze, Xeroform, or Kaltostat). Between three and

seven days postoperatively, the surgeon performs the first dressing change to assess for signs of infection, or possible bleeding (15). Further wound care is often dictated by wound size and the comfort level of the patient. If a significant exudate is present, then a second dressing is applied for another week. Patients are instructed to keep the wound clean and usually sent home with wound care instructions. Use of antibiotic and corticosteroid ointments is individualized to each patient, and is often dependent on surgeon preference (15,16).

Strengths

Secondary intention wound healing is a time-honored and effective method of wound management that is safe, simple, and inexpensive (15–20). It easily allows surveillance for local tumor recurrence, which can be difficult after more complex reconstruction procedures. Wound infection, pain, bleeding, and hypertrophic scarring are all relatively rare.

Weaknesses

The biggest drawback to secondary-intention healing is the unpredictable cosmetic and functional outcome (16). Lid malposition, lid retraction, ectropion, keratitis, and lid notching can all result from granulation tissue with subsequent cicatrix formation. Secondary wound healing takes much longer than primary wound healing, requires additional wound care and does not completely eliminate the need for secondary reconstructive procedures.

Full-Thickness Skin Grafts

Indications

Full-thickness skin grafts are useful for larger, superficial defects that do not involve the lacrimal system. They are preferred in younger patients when aesthetic contour is important (29).

Technique

Choice of donor site for skin grafting the medial canthal area is based on tissue availability, hairlessness, texture, thickness, and color (21). Common donor areas include preauricular skin, retroauricular skin, supraclavicular skin, and contralateral excess upper lid skin. Following harvest, the skin graft is inset into the defect. A quilting stitch through the center of the graft reduces dead space and increases graft take to the underlying bed. A bolster dressing is placed to stent the graft for five to seven days.

Strengths

Skin grafting is technically easy to perform and often heals well in the medial canthal area.

Weaknesses

The most significant drawbacks of skin grafting the medial canthus relate to color mismatch and scar contracture. Though the medial canthus usually heals very well, both hypo- and hyperpigmentation can result in a highly visible graft when sizable (30). Donor site skin harvesting can be difficult at times, particularly from the retroauricular region. Harvesting donor sites can be painful, and problems with healing or wound dehiscence can result in a cosmetically unacceptable scar (21). Inset into deep wounds can leave a large depression. However, this often is not noticeable in the convexity of the medial canthus (20). When necessary, bolsters and dressings can be bothersome to some patients.

Local Tissue Flaps

Indications

Local tissue advancement flaps are the procedures of choice for large (>1.5 cm), eccentric, or deep wounds where periosteum has been sacrificed (29). Surgical judgment is critical when using surrounding local tissue since periorbital skin is often much thicker and does not match well with thinner, more mobile eyelid skin. Multiple techniques have been described; flap choice must be individualized for each defect. Traditionally, the V-Y advancement flap, the glabellar flap, and the Mustarde cheek rotation flap have been the procedures of choice (23–28). The V-Y advancement flap is quite useful for smaller lesions, the glabellar flap for larger, deeper lesions. Their combined use has been shown to be safe and effective (27).

The Mustarde flap can also be used to reconstruct the medial canthus as part of a total lower lid reconstruction.

Techniques

V-Y Advancement Flap

By minimizing tissue tension, the V-Y advancement flap utilizes local tissue for closure of medial canthal wounds (26). Immediately adjacent to the soft-tissue defect, a V-shaped flap is designed that is equal to or slightly less in width than the defect itself. The length of the flap is designed to be one and one-half to two times its width. An incision is carried through the skin only and the subcutaneous tissues are bluntly dissected to mobilize the flap. Gentle traction is applied to the skin edge with hooks to help advance the flap. Primary closure of the donor defect begins at the base of the Y and continues toward the tail of the advanced flap.

Glabellar Flap

Glabellar flaps allow rotation of tissue from the glabella down into the medial canthal region (20,24,28). An inverted V-shaped glabellar flap is designed, incised, and widely undermined. Following rotation into the defect, the flap is inset in two layers. The distal tip may be removed to avoid necrosis and redundant tissue is excised as needed for cosmesis. For larger defects, the glabellar flap can be combined with other flaps or grafts (Fig. 6) (27). Excised tissue can be placed into the donor site, should tight closure cause excessive medialization of the eyebrows (28).

Mustarde Flap

The Mustarde cheek rotation flap and its variations are known to be reliable and useful techniques for repairing large defects of the lower lid (23,25,41). A V-shaped incision is made just inferior to the surgical defect. The flap is elevated subcutaneously, rotated and inset into the defect. The lash-bearing lower lid edge is secured by tacking the tarsal plate at the level of the inferior punctum to the deep portion of the MCT. The remaining skin is then used to fill the gap between the lid stump and the medial edge of the surgical defect.

Strengths

In comparison to skin grafts, local advancement and rotation flaps have superior similarity of skin color, texture, and thickness. Healing is usually faster and they are generally thicker, affording less secondary contraction. They are valuable for deeper defects, particularly when underlying bone and canthal tendon are exposed. Further, most local flaps are relatively simple, fairly adjustable, and quick to perform.

Weaknesses

Secondary procedures are frequently required when debulking, pedicle division, or scar revision is needed. The glabellar flap is significantly thicker than the recipient bed, resulting in a bulky nasal bridge and loss of the natural concavity of the medial canthus. Additionally, it tends to

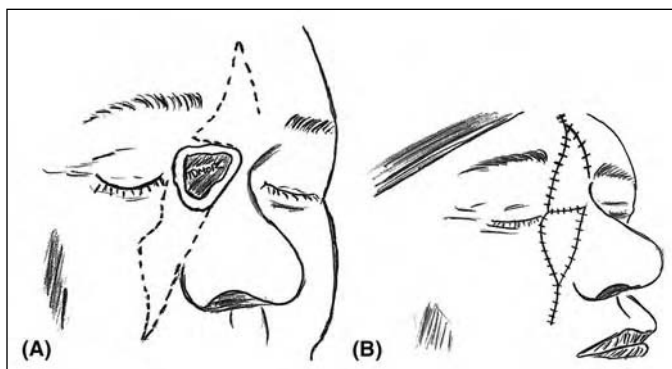


FIGURE 6 Glabellar flap. (A) The lesion to be excised with the flaps are marked out. (B) Closure of the skin flaps and the donor site with interrupted sutures.

draw the medial eyebrows too close to the midline. The Mustarde rotation flap is necessarily broad in magnitude, which can result in a noticeable scar along the cheek.

Myocutaneous Flaps

Indications

Upper eyelid myocutaneous flaps are useful for large, deep, medial canthal defects in which other local cutaneous flaps will fail to provide adequate coverage (20,29,30). They can be used selectively for defects of the inner medial canthus that extend onto the lateral nasal wall. The myocutaneous flap is usually adequate if less than half of the wall is involved and the medial tarsal ligament is undisturbed (29).

Technique

A pretarsal flap or preseptal flap of adequate size is outlined on the upper eyelid, and then incised along the upper border through the orbicularis muscle and down to the tarsus (or septum orbitale) (29). The pretarsal tissues are elevated from lateral to medial, taking care to keep one edge of the flap in continuity with the medial fat pocket. Care is taken to maintain the vascular arcade from the supratrochlear, infratrochlear, and medical palpebral vessels. Once elevated, the flap can be rotated medially into the canthal defect (Fig. 7). Prior to final inset, the CT and lacrimal system are evaluated and reconstructed as needed. The flap is then secured in two layers. The donor site is closed primarily, as in a standard upper lid blepharoplasty.

Strengths

Myocutaneous flaps are supple, reliable, relatively thin, and fairly easy to perform. They provide a well-vascularized, sturdy coverage that has a good tissue match (20,30). Bolster dressings are not required. Donor donor-site morbidities are infrequent.

Weaknesses

Performing myocutaneous flaps from the lid are useful, but can be too large, necessitating secondary debulking procedures. Since this is an axial flap, careless rotation and inset can potentially kink the arterial inflow resulting in partial or total flap necrosis. Further, transient venous congestion can also be problematic.

Medial Canthopexy

Indications

Complex fractures of the nasoethmoid complex commonly create a central bone fragment, resulting in lateral displacement of the medial canthus (42–44,46–48). The MCT usually remains

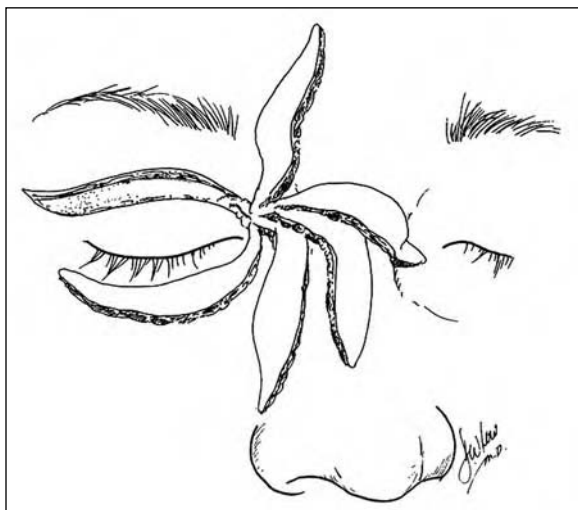


FIGURE 7 Pretarsal flap rotation and design.

attached to this central bone fragment (types I and II NOE fracture), but can be lacerated or avulsed off (type III NOE fracture) (48). Less frequently, medial canthal defects also result from cancer ablation, craniofacial exposure, and congenital abnormalities. Restoration of the native medial canthus anatomy is difficult, since fractures are often comminuted making adequate mini-plate fixation challenging. Medial canthal reconstructive procedures are indicated when suturing alone will not adequately correct canthal displacement (23). Canthopexy and canthoplasty techniques are also helpful in re-establishing normal medial canthal position during craniofacial procedures and midface exposure of the NOE region (31).

Technique

Medial canthopexy and canthoplasty techniques are different for traumatic and nontraumatic injuries. Both employ a coronal incision to provide optimal exposure to the NOE complex and supraorbital rim in a subperiosteal plane (31,42,47). Occasionally, the supraorbital foramen is osteotomized to allow downward mobilization of the flap and pedicle (47). Local incisions should only be used when lacerations are pre-existing (31,42,47). The MCT is identified and carefully dissected. The surgeon must take care to not accidentally disinsert the MCT from the central segment.

Medial Canthopexy for Nontraumatic Injuries

For this, the surgeon creates a depression superior and posterior to the anterior lacrimal crest on the frontal process of the maxilla (31). Two holes, 5 mm vertically apart from each other, are drilled from the glabella through the depression. An 18-gauge needle is passed to connect the holes. A 28-gauge wire is double-passed through the MCT and then through guide needle. Traction is applied to the wire in a postero-superior vector to confirm that it is pulling on the medial canthus before inseting into the depression. Once the MCT is secured in the correct position, the wires are twisted, cut, and closely tucked to the bone recess previously burred in the fronto-glabellar area. The relatively large amount of soft tissue-covering the twisted wire limits extrusion of the wire through the skin.

Medial Canthopexy for Traumatic Injuries

In facial trauma patients, repair of associated fractures is first performed as needed to re-establish the facial buttresses (47). Proper reduction and fixation of the bone segments is performed; titanium plates with 1.0 to 1.3 mm screws are used most commonly. Type I fractures can usually be repaired with mini-plate fixation to the stable surrounding frontal and maxillary segments. Type II fractures require transnasal wire stabilization to restore normal inter-canthal distance. This wiring technique is similar to that described above, except that the transnasal wire is passed through the perpendicular plate and brought out through the opposite orbit, around the contralateral superomedial orbital rim. Placement posterior on the central segment prevents lateral flaring. In cases of unilateral type I and II NOE fractures, the Mitek Anchor System can also be used for segment stabilization (45). Type III fractures frequently require autogenous bone grafting to recreate a central segment onto which the MCT is reattached.

Strengths

Clearly, proper anatomic re-establishment of the medial canthus position is necessary to correct all forms of telecanthus. For nontraumatic injuries, use of the glabellar portion of the frontal bone allows firm fixation of the MCT at its desired position. For unilateral injuries, it also prevents unneeded dissection in the normal contralateral orbit. For traumatic injuries, medial canthal position is dependent on the stability of facial fracture stabilization. Wiring is very useful when bone segments are too small to allow mini-plate fixation.

Weaknesses

Failure to accurately resuspend the periosteum around the orbits and midface can result in soft tissue descent and deformity (47). Medial canthopexy is also associated with a distinct, but low risk of canthal drift (31). Dissection in and around the lacrimal apparatus can cause further injury and long-term dysfunction. Finally, a central spinal fluid leak is possible and must be looked for.

Medial Tarsal Strip

Indications

The medial tarsal strip procedure is indicated for a variety of conditions, including both acquired and congenital medial canthal malposition, medial canthal displacement, canthal tendon laxity, medial ectropion (with a nonfunctioning canalicular system), and rarely, lower lid laxity secondary to facial nerve palsy (32).

Technique

A 4 to 5 mm long full-thickness eyelid incision is made vertically, at the medial aspect of the tarsal plate (32). The lower crus of the MCT is disinserted from the medial edge of the tarsal plate. All scarred tissues medial to the cut edge of the tarsus and above insertion of the MCT are excised. The conjunctiva and lower eyelid retractors are pulled away from the tarsus. A scalpel is then used to scrape the conjunctival epithelium off of the tip of the tarsal strip. The myocutaneous eyelid margin is then separated from the tarsal strip with scissors (Fig. 8). A 4-0 absorbable suture is then used to attach the medial tarsal strip to the stump of the MCT. The suture is tied over the skin to allow the orbicularis muscle and skin to be pulled as posteriorly as possible, giving the appearance of a sharp medial canthal angle.

Strengths

Following a medial tarsal strip, there is minimal recurrence of canthal tendon laxity and elongation (32). The procedure is directed toward the defect site so as to minimize distortion of the tarsal plate, conjunctiva, and tearing mechanism. It is useful in patients with a scarred, severely distorted canthus where other procedures have failed, allowing for a more medial and posterior positioning of the eyelid. Both canthal malposition and eyelid laxity can be corrected concurrently, and the normal almond-shaped canthal angle can also be preserved.

Weaknesses

The only major disadvantage of this technique is that it may require sacrifice of a patent canaliculus, leading to postoperative epiphora (32). Postoperative discomfort and tenderness secondary to the tacking suture have been reported to last up to six weeks. A more pronounced gap between the eyelid and the conjunctiva may occur postoperatively.

CONCLUSIONS

Reconstruction of the lateral and medial canthal regions must take into consideration both form and function of the intricate eyelid structures. Periorbital surgical techniques should be selected in the context of appropriate indications and goals. Every technique has its own inherent

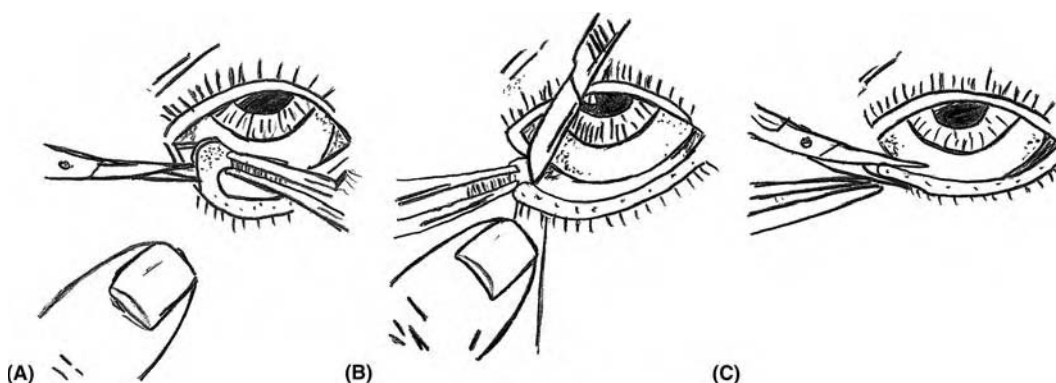


FIGURE 8 (A) Conjunctiva and lower eyelid retractors are disinserted from the tarsus. Scar is undermined to allow mobility. (B) Epithelium is scraped away from conjunctiva over tarsal plate. (C) The myocutaneous eyelid margin is snipped away with scissors.

strengths and weaknesses, as well as benefits and risks. Common surgical pitfalls can be minimized, though not entirely eliminated, through careful patient analysis and appropriate operative selection.

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3 Eyelid Reconstruction

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INTRODUCTION

Plastic surgery of the eyelids is surprisingly complex. Numerous harmoniously functioning structures are delicately interwoven in an extremely compact space, including the eyelid retractors and protractors, portions of the lacrimal drainage and secretory systems, eyelashes, and supportive structures (suspensor ligaments, canthal tendons, and tarsal plates). Neglecting any one component can have devastating consequences. More common eyelid abnormalities amenable to surgical correction are summarized in Table 1. Multivolume text and numerous surgical atlases are dedicated exclusively to ophthalmic plastic surgery (1–3). Comprehensive coverage of this broad field in a single chapter is not feasible. Therefore, this section addresses the evaluation and surgical management of select commonly encountered eyelid abnormalities: dermatochalasis, blepharoptosis, eyelid retraction, lower eyelid malposition (entropion and ectropion), and reconstruction. Detailed descriptions of only the most common and central techniques are provided.

PATIENT EVALUATION

Ophthalmic and periocular evaluation guides eyelid reconstruction and identifies pre-existing abnormalities, which if recognized postoperatively might be wrongly attributed to surgery. Visual acuity is documented and, when less than 20/20, the underlying abnormality identified. Ocular surface examination is necessary to evaluate for various surgical contraindications, discussed in detail next. The retina is evaluated with a dilated fundus evaluation. Pupil and ocular motility evaluation aid in uncovering or excluding neurological and orbital disease, which may effect eyelid position. Altered globe position also suggests orbital disease. Globe prominence, measured with an exophthalmometer, influences the degree to which lower eyelid tightening procedures are performed. The same degree of lower eyelid horizontal tightening in patients with prominent globes may result in retraction, whereas in a patient with relative enophthalmos this may result in eyelid elevation (4). Additionally, the functional impairment of eyelid abnormalities needs documenting. Specifically, in patients with dermatochalasis or ptosis, the degree of visual axis occlusion is documented with photos and formal visual field testing with and without mechanical elevation (i.e., taping) of the eyelids. Further evaluation specific to each given abnormality is discussed in this chapter.

Ocular Surface Disease

Functional integrity is always the primary objective of eyelid surgery; cosmetic appearance, although pertinent, is of secondary concern. Ocular surface disease resulting from surgically induced eyelid malposition can cause anything from mild irritation to permanent vision loss (5). The degree of tolerated exposure varies between individuals, as some patients may be predisposed to corneal drying, epithelial desquamation, and infection.

Dry eye disease is probably the most commonly encountered risk factor for postoperative surface abnormalities. A healthy tear film is dependent upon both quantity and quality of tears. Tear meniscus volume can be assessed at the slit lamp and tear production measured with filter paper saturation. Tear quality is most easily judged by observing the tear film breakup time. Blepharitis or eyelid margin inflammation results in tear film instability. This is evaluated for at the slit lamp and, if warranted, treated prior to elective eyelid surgery. Loss of corneal epithelium

TABLE 1 Abnormalities Commonly Managed with Eyelid Surgery

Blepharochalasis (upper and lower eyelids)
Dermatochalasis (upper and lower eyelids)
Eyelash misdirection
Trichiasis
Distichiasis
Lacrimal drainage system (components located within the eyelids)
Canalicular obstruction
Punctal enlargement
Punctal malposition
Punctal stenosis or occlusion
Lacrimal gland abnormalities
Prolapse
Hyposecretion
Lagophthalmos
Paralytic (e.g., facial nerve palsy)
Mechanical
Malposition (upper eyelid)
Blepharoptosis
Contour abnormalities
Ectropion
Entropion
Floppy eyelid syndrome
Imbrication
Retraction
Malposition (lower eyelid)
Contour abnormalities
Ectropion
Entropion
Retraction
Neoplasm (benign and malignant)
Treatment (e.g., excision)
Reconstruction following excision
Steatoblepharon (upper and lower eyelids)
Symblepharon
Trauma
Eyelid margin laceration
Canthal tendon damage
Levator superioris muscle of aponeurosis laceration
Eyelid avulsion (partial or complete)
Tissue loss (full or partial thickness loss)
Facial dystonia
Essential blepharospasm
Meige syndrome
Hemifacial spasm

integrity is the hallmark of advanced dry eye disease (Fig. 1). When present, the underlying cause is addressed and a conservative approach to surgery is taken.

Numerous abnormalities inherent to the cornea often predispose to ocular surface disease. In the setting of decreased corneal sensation, epithelial decompensation can occur with minimal exposure (Fig. 2). A tendency for corneal epithelium desquamation also exists following traumatic corneal abrasions and with several dystrophies, many of which can only be diagnosed with microscopy (Fig. 3). Corneal herpetic disease is fairly common and not always readily volunteered without specific questioning. It decreased corneal sensation and may also be exacerbated with surgically induced exposure (Fig. 4). Discussion of this added risk should be documented and included in the signed consent.

Previous ophthalmic surgery should be questioned and evaluated. Refractive surgery, namely LASIK, results in ocular drying and a partial loss of corneal sensation. Both contribute to exposure related ophthalmic surface disease (Fig. 5) (6,7). Some glaucoma surgery involves the creation of a subconjunctival aqueous humor drainage site and a “filtering bleb,” usually

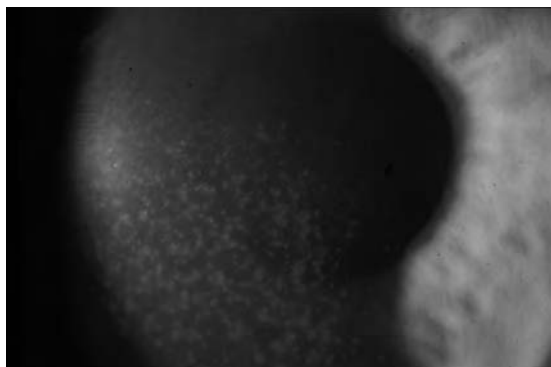


FIGURE 1 Superficial punctate keratopathy signifying dry eye disease. *Source:* Photo courtesy of T.A. Christopher, MD.

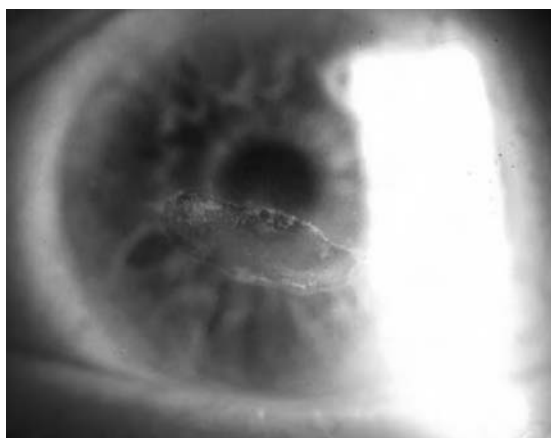


FIGURE 2 Nonhealing epithelial erosion. This resulted from overcorrected blepharoptosis in a patient with decrease in corneal sensation related to systemic amyloidosis.



FIGURE 3 Subtle corneal irregularities seen with retro-illumination in a patient with map-dot-fingerprint dystrophy. Such patients are at increased risk of corneal epithelium desquamation. *Source:* Photo courtesy of Edward Manche, MD.



FIGURE 4 Herpetic keratitis of the left eye (A) exacerbated by mild corneal exposure following aggressive upper blepharoplasty, resulting in poor eyelid closure (B).

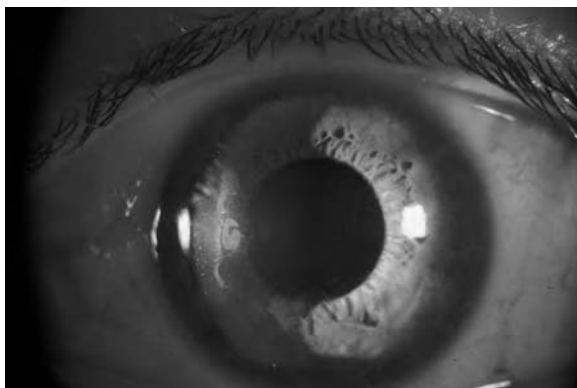


FIGURE 5 Prominent corneal scar following LASIK surgery. *Source:* Photo courtesy of Edward Manche, MD.

located under the upper eyelid. In such patients undergoing blepharoplasty or blepharoptosis repair, extreme care is necessary to avoid overcorrection with bleb exposure.

Anatomy

The dynamic balance between adequate eyelid closure and opening is easily disrupted and favorable outcomes are dependent on an in depth understanding of eyelid anatomy, detailed in Figure 6. Conventionally, the eyelids are considered to be comprised of an anterior and posterior lamella divided by the orbital septum: the anterior consisting of skin and the orbicularis oculi muscle and the posterior consisting of orbital fat, eyelid retractors, tarsus, and conjunctiva. This concept is central to eyelid reconstruction.

Anesthesia

Most eyelid surgery can be performed under local anesthesia with or without conscious sedation. Blepharoptosis and upper eyelid retraction repair in particular, where eyelid positioning requires patient cooperation, are best performed under local anesthesia. For many cases, a short-acting local anesthetic is sufficient. A mixture with longer acting anesthetics is helpful for procedures lasting more than one hour. The administration of epinephrine aids with hemostasis and prolongs the effect of the anesthetic. Buffering with bicarbonate can decrease the pain of injection when given without sedation. Office procedures can be supplemented with oral diazepam to relieve mild anxiety. General anesthesia is reserved for children, uncooperative adults, and some procedures combined with lacrimal drainage or orbital surgery.

BLEPHAROPLASTY

Cosmetic vs. Functional

Blepharoplasty is one of the most commonly performed cosmetic and functional plastic surgery procedures. Patient concerns may be purely functional, cosmetic, or in many cases both. Recognition of this distinction enables surgery to be tailored to individual patient needs. Removal of skin and underlying orbicularis oculi muscle is often sufficient to achieve functional improvement in most. Adjunctive procedures such as fat excision, lacrimal gland repositioning, levator advancement, brow lift, and midface rejuvenation should be considered in patients desiring superior cosmetic improvement, with the understanding that each additional procedure carries further complication risk and cost.

Moderate dermatochalasis can result in loss of superior visual field and when severe central vision. It may simply be due to overhanging skin or less frequently blepharoptosis exacerbation by the added weight. Patient testimony alone is often unreliable, with some unaware of the degree of field loss and others exaggerating it in an effort to recruit aid from their insurance company. A simple guideline one can follow is that visual loss occurs once redundant skin is touching or overhanging the eyelashes; however, formal visual field testing with and without manual eyelid elevation is required to accurately document the presence and degree of field

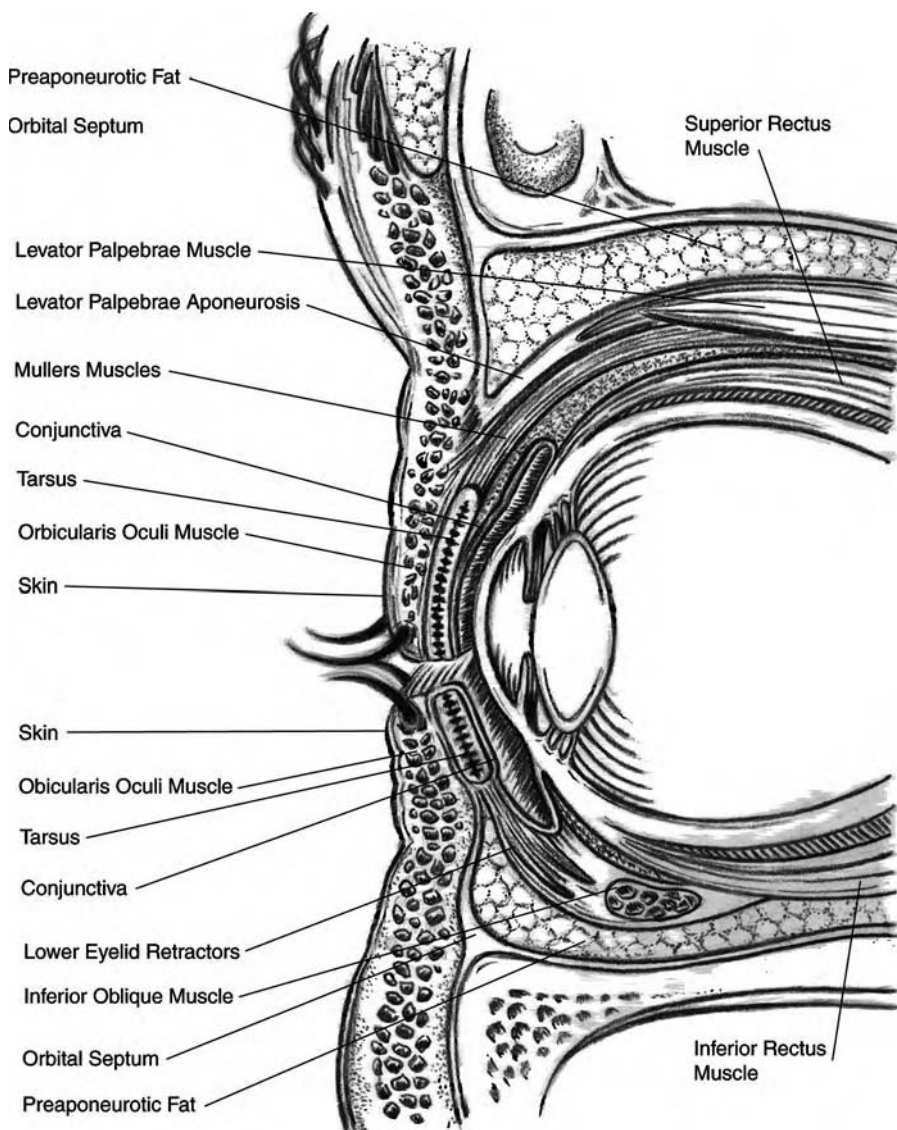


FIGURE 6 Eyelid anatomy (Illustration by Lynda Van, PharmD).

loss. Lower blepharoplasty rarely offers any functional gain and is performed almost exclusively for cosmetic purposes.

Upper Blepharoplasty Technique

Prior to the day of surgery, the desired eyelid-crease height and contour is discussed with the patient. In most individuals, this corresponds to their natural crease. Two notable exceptions are patients with levator aponeurosis dehiscence, in whom abnormal elevation of the crease may be present, and in Asians, who may have no naturally occurring crease.

The first and probably most crucial step in upper blepharoplasty is skin marking, after which surgery is more standardized. Brow height varies slightly between upright and supine positions; consequently, the amount of upper eyelid skin necessary for comfortable closure is slightly less when upright. If the maximal amount of skin to be excised allowing eyelid closure is determined with the patient sitting or standing, incomplete closure is likely to occur when lying down (i.e., sleeping). Therefore, skin marking should always be performed with the

patient relaxed in the supine position. The inferior incision is marked first at the predetermined desired position of the eyelid crease. The upper incision is determined with the eyes closed by placing one end of smooth forceps on the eyelid crease and pinching excess skin delicately in graded increments until slight upturning of the lashes is observed. To further guarantee adequate eyelid closure, measurements should be made to ensure that a minimum height of 20 mm of upper eyelid skin will remain.

Following marking, the eyelids are injected with local anesthetic. An incision is then made around the marked crescent area and the skin with underlying orbicularis oculi excised in one piece. Preservation of some or all of the muscles should be considered in patients with dry eyes. At this point, if lacrimal gland repositioning or fat excision is to be performed, the orbital septum is horizontally incised. Excessive fat excision giving an aged sunken look to the eyes is a more common and less easily rectified error than too little fat removal. Only fat that readily prolapses through the incised septum need be removed. In order to expose the medial fat pad, identified by a slightly more cream coloration than the yellow central fat pad, additional dissection is occasionally required. This should be performed bluntly to minimize injury to the rich overlying palpebral vasculature. Retrobulbar hemorrhage can cause a compressive optic neuropathy and complete visual loss within minutes to hours; therefore, careful attention to hemostasis during fat excision is of critical importance. Also, delicate manipulation of orbital fat is essential. Bleeding can originate from anterior cut blood vessels and deep retrobulbar vessels sheered by traction caused by pulling on anterior orbital fat. In the upper eyelids familiarity with the appearance of the lacrimal gland is essential to avoid inadvertent damage. When prolapsed, the lacrimal gland should never be excised but secured to the lacrimal gland fossa periorbita with one or two permanent monofilament sutures. Lastly, the upper eyelid skin is closed with a running or subcuticular suture. To control eyelid-crease formation, underlying aponeurosis (or anterior tarsus) can be incorporated into the skin closure.

Lower Blepharoplasty Technique

As with the upper eyelids, lower blepharoplasty is individualized. The effect surrounding structures have on the appearance of the eyes/eyelids needs consideration. Often, the prominent appearance of the lower eyelid fat (baggy eyelids) is in part if not entirely due to midface changes (descent and thinning). In such patients, blepharoplasty alone succeeds only in creating a cachectic and aged appearance. Consideration should be given to midface rejuvenation with adjuncts such as fillers, orbital fat repositioning, suborbicularis oculi fat (SOOF) elevation, or midface lift. Abnormal laxity of the lower eyelids should be recognized and repaired at the time of blepharoplasty; otherwise eyelid retraction or ectropion will likely develop.

The primary goal of lower blepharoplasty is removal or repositioning of prolapsed orbital fat. In select patients, dermatochalasis is addressed with cautious skin excision. This should be reserved for patients with marked dermatochalasis. In mild to moderate cases consideration should be given to chemical peeling, dermabrasion, or laser resurfacing performed in conjunction with transconjunctival blepharoplasty. Patients with prominent globes are particularly prone to eyelid retraction; therefore, in such patients skin excision should rarely be considered and when absolutely indicated performed with extreme caution.

Surgery can be performed through either a conjunctiva or cutaneous incision. The transconjunctival approach avoids visible scarring and carries a lower risk of eyelid retraction and contour abnormalities. Following the administration of local anesthesia, the lower eyelid is retracted by passing a 4-0 silk suture through the tarsus at the eyelid margin, which is secured to the adjacent draping. The conjunctiva is then incised approximately 4 mm inferior to the tarsal from just lateral to the puncta and extended to inferior the lateral canthal angle. The incision can be made with any of several equivalent options: fine tip scissors, a 15-blade scalpel, monopolar cautery with a Colorado needle or a CO₂ laser. Dissection is continued directly to the orbital septum, releasing the lower eyelid retractors. The extent of dissection should be minimal to limit scarring and subsequent eyelid retraction. The septum is then incised exposing the underlying orbital fat components; unlike the upper eyelid there are three fat pads: medial, central, and lateral. Prior to fat excision the inferior oblique muscle, which runs between the medial and central fat pads, should be identified to avoid inadvertent damage. Fat excision is continued approximately to the level of the orbital rim; more aggressive excision often results

in a hollow periorbital appearance. As with upper blepharoplasty, careful attention to hemostasis and avoidance of placing tension on the orbital fat are of critical importance. Although some advocate approximating the conjunctiva edges without formal closure, in some cases this likely results in shortening of the fornices. Closure with a running absorbable suture, requiring minimal additional time, should be considered.

The advantage to a transcutaneous incision is the ability to excise redundant eyelid skin. The incision is made approximately 2 to 3 mm inferior to the lash line from just lateral to the puncta to approximately 1 cm lateral to the palpebral fissure. If performed in conjunction with an upper blepharoplasty, the upper and lower incisions should be separated by a minimum of 6 mm to ensure adequate blood supply. Following skin incision, dissection is continued through the orbicularis oculi muscle exposing the underlying orbital septum. Fat is then excised no differently than with a conjunctiva approach. The degree of skin excised should not exceed that, which overlaps the superior incision border when under no tension, usually no more than 1 to 2 mm. A slight lateral transposition of the skin flap allows removal of a slightly greater amount lateral to the canthal angle. Skin closure can be performed with a running absorbable or nonabsorbable suture.

Complications

Probably the most common and avoidable complication is corneal exposure related to eyelid malposition. This is the most common complication of lower blepharoplasty, resulting from either excessive skin excision, scar retraction within the deeper eyelid tissues or failure to calibrate horizontal eyelid tightening to globe prominence (8). With exposure, corneal scarring and infection can result in permanent and complete visual loss. Therefore, until the eyelid position is corrected, comanagement of ocular surface disease with an ophthalmologist should be considered. Nonsurgical management of the eyelids includes massage and steroids, which can be administered topically or by injection depending on the depth of scarring. In more severe cases, surgical intervention may be necessary (described elsewhere).

Severe visual loss is most often related to hemorrhage following lower blepharoplasty. It has been reported to occur roughly once in every 2000 to 5000 cases. (9). Any patient complaining of inordinate pain, asymmetric swelling, proptosis, or blurred vision should be evaluated within the hour. Visual loss from a retrobulbar hemorrhage requires immediate intervention; therefore, visually occlusive dressings that can delay recognition should be avoided. When hemorrhaging occurs, the surgical wound is opened, any hematoma drained and hemostasis established. While making arrangement with the operating room, a lateral canthotomy and cantholysis can be performed, partially relieving elevated orbital pressure. Although their benefit is not well established intravenous steroids are advocated by some and in cases with visual loss should probably be used.

Permanent ocular misalignment and diplopia may result from extraocular muscle injury. The most commonly damaged muscles are the inferior oblique, superior oblique, or inferior rectus muscles (10). Many abnormalities resolve without intervention; therefore, patients should be observed for a period of three to six months. One exception is when complete transection of a muscle is suspected. In such cases, the muscle should be located and sutured in place. When diplopia persists, treatment with prisms, strabismus surgery, and in otherwise unmanageable cases monocular occlusion is employed.

BLEPHAROPTOSIS

Blepharoptosis is defined as an abnormally low upper eyelid position. Normal position varies slightly between and within ethnic groups; therefore, blepharoptosis is defined on an individual basis. Similar to dermatochalasis of the eyelid, mild ptosis may be more of cosmetic than functional concern. However, symptoms are common and can be subdivided into visual loss and fatigue. Initially superior field loss occurs followed by loss of central vision. Secondary elevation of the brow may cause a tired or aching sensation of the forehead. Often worsening in downgaze, patients may initially present with difficulty or fatigue while reading (11). Worsening of both eyelid position and brow ache may occur in the evening as patients fatigue.

Evaluation

Physical evaluation includes measurement of the margin-reflex distance (MRD), levator function (LF), and eyelid crease. MRD, the most useful measure of eyelid height, equals the distance between the eyelid margin and the corneal light reflex with fixating in primary gaze. A normal MRD is approximately 4.0 mm. LF, measured by eyelid excursion from extreme supra to infraduction, is normally about 15 mm and used to evaluate etiology and to direct selection of the appropriate surgical procedure. Eyelid crease evaluation is also used to distinguish etiology, elevation occurs with levator aponeurosis dehiscence and softening with levator muscle paralysis. A history of contact lens wear, eyelid trauma, and intraocular surgery, all of which may result in aponeurotic blepharoptosis, should also be obtained. As outlined above, evaluation should include determination of blepharoptosis-related visual impairment and vigilant ophthalmic examination to identify any contraindications to eyelid elevation.

Aponeurotic Vs. Neuromuscular Blepharoptosis

Although usually attributable to age-related involution of the levator palpebrae superioris muscle aponeurosis, blepharoptosis occurs in the setting of numerous neurological and muscular disorders. In most patients history and examination can distinguish more concerning etiologies. An acute onset, variability in eyelid position, diplopia, proximal limb muscles weakness, shortness of breath, and dysphagia suggest neuromuscular disease. Additionally, in neuromuscular disease, LF is usually reduced proportionally to the degree of ptosis. This contrasts aponeurotic ptosis where LF is relatively preserved (12). Associated findings differ between involutional and neuromuscular blepharoptosis. Involutional ptosis is usually paralleled by a similar degree of periocular changes including dermatochalasis, brow ptosis, and midface descent. The absence of such findings should alert the surgeon to consider alternate etiologies. Neuromuscular disorders often affect pupil size and ocular motility, which require careful examination prior to considering surgery.

Aponeurotic Blepharoptosis

Aponeurotic abnormalities, degeneration, and dehiscence are the most commonly encountered and easily corrected types of blepharoptosis. Although usually occurring with age-related involution, aponeurosis damage is encountered in numerous settings. Ptosis is not an uncommon consequence of chronic contact lens use (13). When contact lens wear is a contributing factor, patients should stop use and be evaluated in one to two months. Occasionally, normalization of eyelid position occurs without further intervention. When surgical correction is indicated, patients should be advised that continued contact use might result in early recurrence. Aponeurosis damage may be a direct result of trauma. Blepharoptosis is also occasionally encountered following intraocular surgery (14). Aponeurosis damage probably results from trauma related to the use of an eyelid speculum. Knowledge of this potential complication is most important with regards to the timing of blepharoptosis repair, which should always be performed following and not prior to intraocular surgery. The reverse order would likely result in an undoing of any surgical eyelid elevation.

Neurogenic Blepharoptosis

Blepharoptosis results from paralysis of either the levator superioris muscle or the sympathetically innervated Muller's muscle. The oculomotor or third cranial nerve (CNIII) carries fibers that innervate the pupil sphincter and five extraocular muscles including the levator muscle. The nerve branches near its target muscles and isolated ptosis due to CNIII injury is extremely uncommon. Although, with CNIII palsy associated abnormal ocular motility and/or pupil dilation almost invariably occurs, isolated neurogenic ptosis has been described as the first sign of compressive lesions and following trauma (15–19). These uncommon cases can be identified by reduced LF, which decreases proportionally to the degree of ptosis. Interruption of sympathetic nerve supply to Muller's muscle (Horner syndrome) results in approximately 2 mm of ptosis. In most cases, Horner syndrome is easily recognized by associated findings: miosis, lower eyelid elevation, periorbital anhidrosis, and relative ocular

hypotony. The diagnosis is confirmed by the lack of pupil dilation with topical application of cocaine.

The most common systemic disease resulting in blepharoptosis is myasthenia gravis. Ophthalmic involvement occurs at presentation in 70% and sometime during disease course in 90% of cases (20,21). All patients with ptosis should be questioned for variability in eyelid position, diplopia, proximal limb muscles weakness, shortness of breath, and dysphagia. Early fatigue, although not invariably present, should be tested in all blepharoptosis patients. Any worsening of ptosis with prolonged upgaze is abnormal and suggestive of myasthenia. Another simple office test is an "ice pack test," in which eyelid position is assessed before and after resting with topical application of ice. An MRD increase of 2 mm or more occurs in many myasthenia patients (22). When myasthenia is suspected, either by history or by examination, surgical correction should be postponed until further evaluation, possibly including serum antibody assessment, edrophonium chloride testing, and electromyogram.

Aberrant nerve supply of either the orbicularis oculi or levator muscle may result in blepharoptosis. This is most commonly encountered with nerve regeneration following idiopathic or viral seventh nerve palsies. Increased basal orbicularis tone results in eyelid ptosis at rest. This is usually compounded by worsening blepharoptosis with lower facial movement; patients often complain of fluctuations when eating or speaking. Other uncommon syndromes with synkinesis are usually readily recognizable. Marcus Gunn jaw-winking syndrome, for example, is a congenital aberrant neural connection between the pterygoid muscles and levator superioris muscle where ptosis is present at rest and eyelid elevation occurs with jaw movement (23).

Myogenic Blepharoptosis

Congenital blepharoptosis, the most commonly encountered myogenic etiology, can usually be distinguished with history alone or by reviewing childhood photographs. The hallmark of the examination is limited eyelid excursion. Careful measurement of LF is needed to determine appropriate surgical technique. Acquired myogenic blepharoptosis is relatively uncommon. Etiologies include several mitochondrial disorders, such as chronic progressive external ophthalmoplegia, myotonic dystrophy, and a number of inflammatory and infiltrative processes such as lymphoma, sarcoidosis, amyloidosis, and idiopathic myositis. Most do not occur in isolation and are accompanied by additional extraocular or systemic muscular abnormalities.

Blepharoptosis Management

Management is directed at the specific abnormality with many cases handled without surgery. When present, any underlying neurological or other systemic disease is treated. Another example where surgery is avoided is synkinesis related to aberrant seventh nerve regeneration, where prudent use of botulinum toxin achieves a desirable result (Fig. 7). In contrast, some cases require a rather complex surgical approach. For example, in Marcus Gunn jaw-winking syndrome the levator muscle is disinserted followed by placement of frontalis sling, with symmetry achieved by similarly altering the normal contralateral eyelid (24). In most cases, blepharoptosis is managed with one of the three following procedures: frontalis muscle suspension or "sling," transconjunctival Mullerectomy, or external levator advancement. LF is the most important determinant in choosing the ideal surgical correction.

When LF is poor, usually defined as 6 mm or less, the frontalis muscle is recruited to aid in eyelid elevation. Numerous variations in technique have been advocated; however, all involve direct suspension of the eyelid from the frontalis muscle, such that brow elevation results in eyelid elevation. Various materials can be used. Good long-term results are achieved with autogenous fascia lata (25). However, this requires a second surgical site and a patient of sufficient size for harvesting, roughly three years of age or 35 pounds. With congenital ptosis being the most common indication and many young patients requiring surgery, alternate materials are becoming increasingly popular, including banked fascia lata and synthetic material such as silicone rods, polytetrafluoroethane (GORTEx), and large caliber permanent sutures (17,18,26). Synthetic materials have the added benefit of being more easily adjusted or removed.

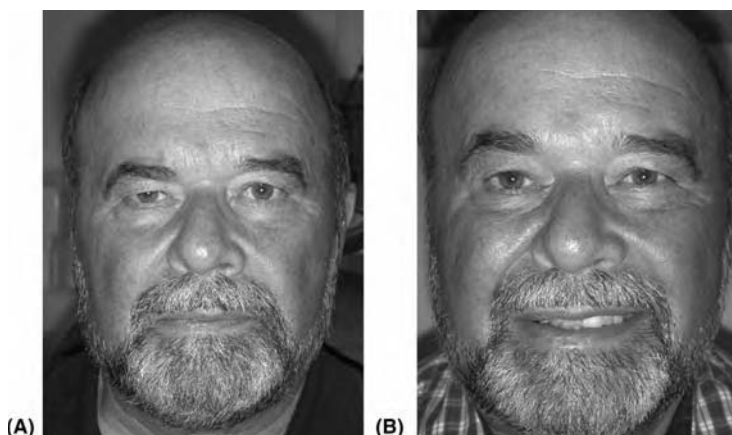


FIGURE 7 (A) Blepharoptosis, due to facial nerve synkinesis, and brow ptosis, due to frontalis paralysis. (B) Correction of both eyelid and brow position with botulinum toxin B injection to the orbicularis oculi muscle and brow depressors.

Mild blepharoptosis can be treated with transconjunctival repair, the two most common techniques being excision of Muller's muscle with (Fasanella-Servat repair) or without (Mullerectomy) resection of the superior tarsal plate (27,28). Fasanella-Servat repair has largely been replaced with simple excision of Muller's muscle, which results in fewer contour abnormalities. This repair is ideal for patients with Horner syndrome where the weakened muscle is excised. A Mullerectomy should also be considered in patients with mild ptosis and an indistinct eyelid crease within which to hide an external incision. Mullerectomy should probably be avoided in patients with limited LF, because the loss of Muller's muscle results in an additional 2 mm decrease in eyelid excursion.

External levator advancement provides several advantages: it can be used for a wide range of blepharoptosis severity; intraoperative adjustment of eyelid height and contour is possible; an eyelid crease can be created or adjusted; and it can be performed in conjunction with blepharoplasty. It is used in patients with good LF and in a graded fashion in those with moderate LF. Previously, excision of a section of the levator muscle itself was advocated. This has been refined with the less barbaric aponeurosis advancement, which addresses the anatomic abnormality, provides superior hemostasis, and is more easily adjusted intra- and postoperatively (29). Surgical technique is detailed next.

External Levator Aponeurosis Advancement Technique

The minimum volume of local that achieves adequate anesthesia is used, usually 1 ml per eyelid. Larger volumes affect eyelid position precluding accurate intraoperative adjustment. The edge of the levator superioris aponeurosis and superior tarsus is identified through a lid crease incision. The orbital septum and preaponeurotic fat are then dissected from the aponeurosis and retracted superiorly. Skin and orbicularis oculi muscle are dissected from the superior third of the entire tarsal width and retracted inferiorly. If not already present, a dehiscence of the aponeurosis can be created surgically. The inferior aponeurosis edge is then advanced and fixed to the anterior tarsal surface using a single 6-0 nylon horizontal mattress suture placed slightly nasal to the pupil. The magnitude of advancement is determined individually, based on the degree of aponeurosis dehiscence and degeneration, amount of adipose infiltration of the levator superioris muscle, and amount of preoperative ptosis. The patient is then placed in a sitting position to assess eyelid height. If not at the desired level, the degree of advancement is then adjusted. An intraoperative eyelid height equal to or slightly greater than the desired postoperative eyelid position should be achieved in all cases. Additional 6-0 nylon sutures are placed as needed to sculpt contour. Skin closure and eyelid crease formation are performed identically as described for blepharoplasty. When desired, upper blepharoplasty is performed in conjunction with ptosis repair.

Complications

Potential complications include those described following blepharoplasty. When performed by an experienced surgeon, levator advancement enjoys a high success rate, with the most common unwanted outcome being an undesirable eyelid position. Despite precise intra-operative placement of eyelid position, roughly 5% of unilateral and 12% of bilateral cases will require supplementary adjustment (30). Sometimes unexpected complication of unilateral repair is the precipitation of contralateral blepharoptosis, mediated through a bilateral equal decrease in neural tone (31). Additional complications include indistinct or irregular eyelid creases, which can usually be rectified with limited blepharoplasty and tarsal fixation. Abnormal eyelid contour is corrected with further aponeurosis modification. A posterior exposed suture should be suspected with corneal epithelial abnormalities in the absence of exposure.

ECTROPION

Ectropion is an outward turning of the eyelid. Mild ectropion may be initially well tolerated; however, chronic exposure leads to palpebral conjunctiva scarring, keratinization, and thickening. Subsequent ocular surface disease develops as a result of both corneal exposure and contact with a keratinized surface. Early repair not only prevents this complication but is more easily performed prior to eyelid distortion. Ectropion is often classified as involutional, paralytic, cicatricial, and mechanical. With many cases caused by a combination of more than one abnormality, repair is tailored such that each component is addressed. The types of ectropion and corresponding management are discussed separately.

Involutional Entropion

The most commonly encountered cause of ectropion is age-related involution, which is not only encountered in isolation but often compounds the degree of ectropion resulting from other causes. Involutional ectropion results from laxity of the eyelid's supporting tissues and occurs almost exclusively in the lower eyelids. Horizontal laxity results from stretching of the medial and to a greater extent, the lateral canthal tendon. Degeneration or dehiscence of the lower eyelid retractors may occasionally be contributory.

Repair addresses specific structural abnormalities. When needed, the medial canthal tendon can be plicated through a small cutaneous or caruncular incision (32). This should always be performed with a wire probe in place, spanning from the puncta to the lacrimal sac to prevent damaging the underlying canaliculi. Rarely, attachment of the lower eyelid retractors is necessary. This is useful in severe cases with complete tarsus eversion, "tarsal ectropion" (33). Specific technique for retractor repair is described in the section on entropion. Correction of lateral horizontal laxity is achieved with eyelid shortening. The Bick procedure, a crude simplistic approach, involves a lateral wedge excision including portions of both the tarsus and lateral canthal tendon with primary closure (34). This often results in a cosmetically unacceptable rounding of the lateral canthal angle and has limited usefulness. The hallmark of involutional ectropion repair is horizontal tightening via a lateral tarsal strip procedure, sometimes referred to as a lateral canthoplasty or canthopexy, described in detail next.

Tarsal Strip Technique

The aim of the lateral tarsal strip operation is to shorten the lateral canthal tendon and, in select cases, the tarsus. The initial step is a lateral canthotomy, where the lateral canthal tendon's superior and inferior crus are split; scissors are used to cut both the tendon and overlying skin from the canthal angle laterally approximately 5 mm. The inferior crus of the canthal tendon is then cut. This cantholysis frees the eyelid from its attachment to the lateral orbit rim. The eyelid is then divided into its anterior and posterior lamella exposing several millimeters of tarsus. The conjunctiva and lower eyelid retractors are cut from the inferior tarsal border and the epithelium from the superior tarsal border. The lateral orbital rim periorbita is exposed with blunt dissection. The eyelid position is then assessed by gently grasping the

tarsal strip with small tooth forceps and holding it against the inside of the lateral orbital rim. Eyelid distraction (the distance the eyelid can be displaced from the globe with minimal tension) should be roughly 2 mm. If the eyelid is too tight, dehiscence will occur. In cases with increased globe prominence, an eyelid distraction of greater than 2 mm may be required to avoid pulling the eyelid under the globe creating unwanted retraction. If further tightening is necessary the tarsal strip can be shortened. Following any needed adjustment, the tarsus is sutured to the periorbital overlying Whitnall's tubercle. The upper and lower eyelid margins are then approximated with a buried absorbable suture followed by layered closure of the orbicularis oculi muscle and skin.

Cicatricial Entropion

Anterior lamellar scarring may cause or contribute to ectropion. Overly aggressive transcutaneous blepharoplasty and actinic damage are commonly encountered. Other etiologies include scarring related to mechanical trauma, laser resurfacing, and malignancy. Reconstruction should address coexisting involution. Horizontal tightening is sufficient only in the mildest of cases. In the majority of cases, early recurrence is inevitable without addressing the cicatricial component. Many techniques are available; all have the common goal of vertical elongation of the anterior lamella. Most cases are managed with full-thickness skin grafting or flaps (cutaneous and myocutaneous). In select cases where cosmetics are of particular concern, such as following a misadventurous blepharoplasty, a midface lift functions effectively as rather large myocutaneous advancement flap. A particularly useful option is an upper to lower eyelid myocutaneous transposition flap, which addresses not only the ectropion but upper eyelid dermatochalasis. This has the further advantage of transposing similarly appearing skin and adding muscular support to the lower eyelid. Details of additional techniques are discussed with reconstruction of the anterior lamella.

Paralytic Ectropion

Orbicularis oculi paralysis causes a loss of lower eyelid support and subsequent ectropion. This is most commonly due to seventh nerve palsy. Other etiologies such as overgenerous injection of botulinum toxin are occasionally encountered. Management of paralytic ectropion is often complicated by the myriad of abnormalities found with facial nerve palsy. Exposure is compounded by upper eyelid lagophthalmos. Another common symptom, epiphora, results not only from lower eyelid malposition but also from exposure related to upper eyelid position, interruption of the lacrimal pump and lacrimal gland dysfunction. In short, be careful of wrongly attributing symptoms to lower eyelid position by not recognizing coexisting abnormalities. This is a common failing and source of disappointing surgical results.

The initial step is to determine the cause. The importance with regards to management is to estimate the duration of paralysis. If function is expected to return, such as with Bell's palsy or a botulinum faux pas, only temporary measures need to be taken. This includes aggressive topical lubrication for corneal protection and prevention of conjunctiva keratinization. Also, the lateral aspect of the eyelid can simply be taped. Alternately, the eye can be taped shut entirely, which is often the best choice when sleeping. A tarsorrhaphy, either with or without creation of an intermarginal adhesion, can be used when less aggressive measures fail. When paralysis is not likely to resolve, more involved surgical correction may be required. In many cases, horizontal tightening procedures achieve the desired result. With complete paralysis added support in the form of a suspension sling may be required. Success has been reported with various materials including fascia lata, silicone rods, and polytetrafluoroethane (Gortex®) (35). Additionally, correction of midface descent, a common consequence of facial nerve palsy, may alleviate tension on the eyelid (36).

Mechanical Ectropion

Mechanical ectropion refers to the effect of a mass either pulling or pushing the eyelid away from the globe. This is usually readily recognizable. Management focuses on treatment or removal of the mass with subsequent eyelid reconstruction.

ENTROPION

Entropion is the inward rotation of the eyelid. Mechanism and treatment parallel ectropion. Etiologies can be categorized as involutional, cicatricial, and mechanical. Orbicularis oculi spasm can also cause inward turning of the eyelids. Patients tend to be extremely uncomfortable due to eyelashes touching the cornea. More importantly, they are at a particularly high risk of corneal infection. The lashes deposit bacteria directly on the ocular surface and furthermore disrupt the corneal epithelium, which normally serves as a barrier to bacteria penetration. Correction, therefore, is performed in a timely fashion and temporary measures are taken until definitive treatment is possible. Patients should probably be evaluated and followed by an ophthalmologist to assess the cornea for signs of infection and initiate treatment or preventative measures as indicated.

Diagnosis is made simply by observing eyelid position. Entropion may be intermittent and missed without proper evaluation. If entropion is suspected by history or characteristic cornea appearance, patients are instructed to tightly close their eyes precipitating rotation in intermittent cases. The one abnormality commonly mistaken for entropion is misdirection of the eyelashes, trichiasis, or distichiasis. Therefore, when diagnosing entropion, attention is directed at the eyelid margin, not the lashes. Patients are evaluated for sources of ocular irritation that might trigger orbicularis oculi spasm. Slit lamp examination is needed to exclude various corneal diseases, intraocular inflammation as a source of irritation, and to evaluate the palpebral conjunctiva for inflammation and scarring.

Involutional Entropion

Age-related involution is the most common cause of lower eyelid entropion. Contributing factors include laxity of the canthal tendons and disinsertion of the lower eyelid retractors. Overriding orbicularis oculi muscle may cause further eyelid rotation.

While awaiting more permanent correction, temporary eyelid aversion is achieved with "Quickert sutures" (37). Three to five sutures are placed in a mattress fashion, each spanning the full eyelid thickness from the inferior fornix conjunctiva to just inferior to the lash line. Definitive repair is tailored to address each contributing factor. Horizontal laxity is corrected with a tarsal strip procedure as previously described. Rarely, medial canthal tendon plaction is necessary. In contrast to ectropion repair, the lower eyelid retractors should almost invariably be reattached. Many techniques of retractor repair have been described. One relatively crude technique involves a full-thickness horizontal incision of the eyelid, which is then rotated and sutured in place (Weis procedure). This results in excessive scarring and distortion of the normal eyelid architecture making future reconstruction difficult. Although occasionally resorted to in recalcitrant cases, the Weis procedure has largely been replaced with more refined techniques. Quickert sutures achieve advancement of the retractors. Although traditionally considered a temporizing measure, good long-term results have been reported when performed in conjunction with horizontal tightening (38). Long-term correction is probably more consistently achieved with direct visualization and suturing of the lower eyelid retractors to the tarsus. This can be performed through a conjunctiva or cutaneous approach. A conjunctiva approach has the advantage of avoiding a visible scar (39). However, a transcutaneous approach allows excision of overriding skin and orbicularis oculi muscle. Moreover, surgical cicatricial changes of the anterior eyelid lamella aid in outward eyelid rotation, whereas conjunctiva scarring encourages entropion recurrence. Therefore, unless a proper comparative study demonstrates otherwise, transconjunctival repair should probably be reserved for cases where cosmetics are paramount. The specific technique of transcutaneous retractor repair is described next.

Transcutaneous Lower-Eyelid Retractor Repair

Reinsertion of the lower eyelid retractors is usually performed in conjunction with horizontal tightening. Most often a tarsal strip procedure is initially performed. Prior to closure of the canthotomy, a subciliary incision is made from the existing lateral incision to just lateral to the inferior puncta. The lower eyelid retractors are then identified following dissection through the orbicularis oculi muscle. Occasionally, to locate the leading retractor edge, the orbital septum

must be incised and pulled inferior along with underlying orbital fat. A thin strip of orbicularis oculi muscle and overlying skin, if marked dermatochalasis is present, is excised exposing the inferior tarsal border. The retractors are then secured to the tarsus using one to three 6-0 permanent monofilament sutures, placed in horizontal mattress fashion. Skin is then closed with a running absorbable suture with deep tarsal bites used to fix the anterior lamella, further precluding overriding of the orbicularis oculi muscle.

Acute Spastic Entropion

Acute spastic entropion refers to inward eyelid rotation secondary to orbicularis oculi spasm caused by ocular irritation or inflammation. It is encountered in many settings, including following intraocular surgery and with ocular surface disease. A vicious cycle developed as eyelid rotation results in eyelashes contacting the cornea causing further irritation. Treatment is directed at removal of any irritant. Temporary relief may be achieved with eyelid taping or in recalcitrant cases Quickert sutures.

Cicatricial Entropion

Posterior lamellar scarring causing inward eyelid rotation is encountered in a variety of settings including pemphigoid, Stevens-Johnson syndrome, infection (trachoma and herpetic disease), chemical and mechanical injury. Iatrogenic cicatricial entropion is occasionally encountered following surgery involving the conjunctiva including posterior blepharoptosis repair and enucleation. Cicatricial entropion is distinguished by history and examination of the palpebral conjunctiva surface. It should be suspected when the eyelid cannot easily be everted with digital pressure.

Prior to surgical correction, any causative abnormalities should be controlled. Multiple surgical options are available. Alternatively, with limited distortion of the eyelid architecture, the anterior lamella including the eyelashes can be excised and replaced with a mucous membrane graft. When tarsal “kinking” is present, a tarsal fracture operation is useful. In this procedure, the tarsus is incised 2 mm posterior to the eyelid margin, rotated and sutured in place (40). More severe cases may require reconstruction of the posterior lamella with a mucous membrane or hard palate graft (41).

EYELID RETRACTION

Retraction refers to displacement of the eyelids such that sclera shows between the eyelid margin and corneal limbus. Minimal retraction, particularly of the lower eyelids, may be a normal variant. Consequences range from mild irritation to corneal decompensation. Mild cases may be managed with topical lubrication, whereas more severe cases may require extensive reconstruction. Upper and lower eyelid retractions differ greatly with regards to etiology and management and are discussed separately.

Upper Eyelid Retraction

The most common cause of upper eyelid retraction is thyroid-related eye disease (Graves ophthalmopathy). Retraction due to overcorrected blepharoplasty or blepharoptosis, orbicularis oculi paresis, and ocular surface inflammatory syndromes are also relatively common. Unilateral blepharoptosis occasionally results in retraction of the contralateral eyelid (42). The following are some examples of less frequently encountered etiologies: surgical recession of the superior rectus muscle, dorsal midbrain syndrome, hepatic failure, and some synkinesis syndromes (43).

Topical lubrication is used to treat mild cases and as a temporizing measure in more severe cases. When possible, surgical correction is postponed until eyelid position has stabilized. Retraction resulting from eyelid surgery and associated with thyroid disease notoriously fluctuate, with some cases progressing and others resolving spontaneously. Numerous surgical approaches have been described. A tarsorrhaphy is a straightforward but cosmetically lacking option. It is most useful in medically unstable patients where cosmetics are of secondary

concern. A tarsorrhaphy can also be used on a temporary basis while awaiting stabilization. Retraction related to facial nerve palsy is well treated with placement of a gold weight. In thyroid eye disease, good results can usually be achieved with levator aponeurosis recession with or without a spacer or “hang-back” sutures. When levator recession alone is insufficient, Muller’s muscle can be excised. When thyroid eye disease results in both eyelid retraction and ptosis, orbital decompression addresses both abnormalities.

Lower Eyelid Retraction

Sources of lower eyelid retraction parallel those of the upper eyelid and include thyroid eye disease, trauma, and ocular surface inflammation. However, it is most often encountered as a complication of lower blepharoplasty. Contributing factors include excessive skin excision, scarring of the deeper tissue, and failure to appropriately address horizontal laxity, either by neglecting to correct existing laxity or by overtightening in patients with prominent globes.

Management depends on the etiology. When present, inflammation or other causative factors are treated. Topical lubrication is sufficient in some mild cases and is a helpful adjunct in more severe cases. Choice of surgical correction depends on both severity and depth of retraction. In mild cases, correction of excess horizontal laxity may be sufficient. Unfortunately, any elevation achieved from further tightening of an eyelid with normal horizontal tension will be short lived, with almost certain complete recurrence.

When horizontal tightening is not sufficient, mucosal grafting or spacers are used to manage posterior lamella scarring and skin grafting or flaps with anterior lamellar scarring. However, many find a visible skin graft to be an unacceptable option. In such cosmetically motivated patients, posterior spacers used in conjunction with horizontal tightening can achieve a small amount of elevation, even when retraction is due to anterior lamellar scarring shortening. This is often a reasonable solution for mild to moderate retraction following blepharoplasty. Numerous materials have been described as effective posterior spacers. Kersten et al. first described the use of hard palate grafts in the correction of eyelid retraction (44). Hard palate grafts have the advantage of inciting minimal inflammatory response and being well tolerated by the cornea. More rigid ear cartilage probably achieves a slightly greater lift but is often palpable and in some cases visible. In more advanced cases lengthening of the anterior lamella is necessary, which often can be achieved with a SOOF or midface lift (45). In the most severe cases no alternative may exist to skin grafting.

EYELID RECONSTRUCTION

Soft-tissue damage most commonly results from trauma and malignancy excision. Less common causes include congenital defects, radiation necrosis, necrotizing fasciitis, and mucor mycosis infection. Similar surgical principles apply to defects that result from various etiologies and are discussed together. With any injury the initial step in planning repair is determining the extent of damage. With trauma, the eye is evaluated initially. Manipulation of the eyelids can be detrimental in the setting of certain ocular injuries. For example, if the globe is ruptured, periocular pressure can cause extrusion of intraocular contents. Ocular injuries generally receive priority and are repaired first. Depending on the nature of the trauma, imaging is obtained to evaluate bone injury and to locate orbital foreign bodies. Inspection of the eyelids includes evaluation of the canthal tendons, eyelid margin, anterior and posterior lamella, levator muscle and aponeurosis, and the lacrimal drainage system. Visible orbital fat denotes violation of the orbital septum and alerts to the possibility of orbital injury or foreign body. The degree of soft tissue loss is also assessed; missing tissue is uncommon in trauma but often presents a challenge following malignancy excision. Full-thickness eyelid defects are unique and when large require a complex approach. Repair of each structure is discussed individually.

Lacrimal Drainage System

Repair of the lacrimal drainage system is detailed in a separate chapter. However, a few brief comments are relevant to this section. Often the only chance to establish adequate outflow is with initial reconstruction and should not be neglected. When lacerated the canaliculi are

approximated over silicon tubing. If only the distal canaliculus remains it can be either marsupialized or redirected to the eyelid margin. When the canaliculus is completely absent or damaged beyond repair, a conjunctivodacryocystorhinostomy (CDCR) can be performed as a secondary procedure. However, CDCR is ridden with shortcomings and should be viewed as a last resort (46).

Medial Canthal Reconstruction

Goals of reconstructing medial canthal defects include protection of the globe, attachment of the medial canthal tendon or creation of a substitute eyelid attachment, and establishment of lacrimal outflow. When missing or damaged the following structures need restoration: mucosa, tarsus, skin, canthal tendon, and lacrimal drainage structures. Avoiding anterior/medial tension prevents displacement of the eyelids from the globe. On the other hand, failing to properly secure the eyelid medially results in lateral displacement of the canthus (telecanthus). Additionally, proper function of the lacrimal drainage system is dependent on precise placement of the medial canthal tendon, which is intimately connected with the canaliculi.

When a defect involves the medial canthal tendon, attention is first given to fixation of the eyelid. When the tendon is lacerated the cut ends are simply approximated and sutured. If a portion of the upper or lower eyelid is missing, the cut tarsal edge can be directly sutured to the tendon remnant. For larger eyelid defects one of the full-thickness eyelid lengthening procedures (discussed elsewhere) can be performed in conjunction with canthal reconstruction.

If the medial canthal tendon is lost, the tarsal edge or reconstructed tendon is fixed to bone nasally. A slew of nasal fixation techniques have been described. A tarsal strip can be formed in a similar fashion to the lateral tarsal strip technique (described under Ectropion Repair). The medial tarsal edge is then sutured with a nonabsorbable suture to the periosteum. To prevent anterior displacement, the eyelid is fixed to the posterior lacrimal crest; this may require anterior reflection of the lacrimal sac. If the lacrimal drainage system is intubated, the suture is placed posterior to the canaliculus (47). As an alternative, the orbital periosteum can be used to create a flap to suture the remnant tarsus (48).

When the periosteum is absent in the desired position, fixation directly to bone is possible. Although transnasal wiring is frequently employed, consideration should be given to one of the numerous available methods of unilateral fixation. In one technique, a portion of the lacrimal sac fossa bone is removed and a 30-gauge stainless steel wire passed through two holes drilled through the lacrimal crest. The medial canthal tendon is either attached directly or probably preferably sutured to the wire (49–51). An alternate method involves the creation of a bony strut to which the tendon is sutured (52). Lastly, the tendon can be sutured to either a specially designed screw, with a “hole in its head,” or a miniplate (53–55). When bone is missing from the desired fixation point, there is a more limited selection of surgical options. If the surrounding bone is intact, the tendon can be attached to a miniplate, which spans the bony defect. In the complete absence of bony support, one can resort to transnasal wiring.

Once the eyelid is structurally secure, skin and muscle defects are addressed. Small defects are closed directly. Surrounding skin can be undermined and advanced to varying degrees depending on skin laxity. Superficial defects up to 1.5 cm that are vertically centered relative to the palpebral fissure often heal well by secondary intention. Off center defects tend to cause vertical canthal/eyelid displacement toward the midpoint of the defect. Epithelialization usually occurs in two to three weeks with daily placement of antibiotic ointment and dressing changes (56).

For defects too large to be closed directly and when secondary intention would not achieve the desired results skin grafting or flaps are utilized. Myocutaneous advancement flaps can be created from both the upper and lower eyelids. In the lower eyelid, a subciliary incision is made that spans the entire eyelid length. Dissection in the suborbicularis oculi plane is extended to the superior cheek. The flap is then rotated/advanced medially and fixed to periosteum. Care must be taken not to place the eyelid under any vertical tension. A myocutaneous flap can similarly be formed in the upper eyelid. The inferior boundary lies in the eyelid crease with the upper boundary dependent on the amount of excess skin. This is determined in the same fashion as with upper eyelid blepharoplasty. Depending on the location of the defect, the resulting

flap is advanced or rotated. Longer flaps can be transposed on a medially based pedicle. Although it is not truly a vascular pedicle, this tissue is generously vascularized and may be placed over a minimally vascularized bed.

With defects too deep or large to be closed with an eyelid flap, a glabellar flap may be used. This involves undermining a vertically oriented V-shaped flap with its base at the glabella. The horizontal width of the flap base is matched to the vertical width of the defect. The flap is then rotated into place and shortened to the desired length. The donor site is closed directly in a V to Y fashion. A larger flap can be created by extending a glabellar flap in depth and length onto the forehead (midline forehead flap). This flap is relatively bulky and should be reserved for large deep wounds. The maximum width is around 2.5 cm and the length should not be greater than five times its width. Redundant tissue at the base of the flap often requires debulking as secondary procedure. Midline forehead flaps have an added advantage; when the medial portion of either eyelids is missing, the forehead flap can lined posteriorly with a mucous membrane graft and used for eyelid reconstruction. With upper and lower defects it can be bisected and used for both eyelids. This flap is relatively immobile due to its thickness and, although this is acceptable with large lower eyelid defects, only the smallest of lateral upper eyelid defects can be reconstructed with median forehead flaps.

For superficial defects with minimal muscle loss, full-thickness skin grafting works well. Skin must be harvested from nonhair bearing areas. Based on the matching appearance choice of donor site in descending order is (i) ipsilateral or contralateral upper eyelid, (ii) retroauricular, (iii) preauricular, (iv) supraclavicular, and (v) the volar aspect of the upper arm. A template of an irregular defect can be made by pressing sterile paper (e.g., suture packaging) against the recipient site creating a blood imprint. A graft is outlined and harvested that is 20% to 30% larger than the template. Once sutured into place, firm graft to bed contact can be achieved by several methods. Full-thickness sutures can be placed centrally. Also, a bolster can be placed over the graft and secured with silk sutures or alternately be held in place with a firm eye patch.

Anterior Lamellar Reconstruction

Treatment options of anterior lamellar defects include primary closure with or without undermining and advancement of adjacent tissue, myocutaneous flaps, and free skin grafts. Although healing by granulation of small areas is occasionally an acceptable alternative in the medial canthus, contraction often results in eyelid distortion. Lacerations without tissue loss are closed primarily in a layered fashion. Small upper eyelid and lateral canthal defects can often be repaired without tissue transfer. Little redundant skin is available in the lower eyelids; therefore even the smallest of defects may require more involved reconstruction. When primary closure would result in vertical tension or distortion of eyelid contour, advancement/transfer of adjacent tissue is considered. Within the orbital rim undermining is usually best performed in the preseptal (suborbicularis) plane. When undermining extends to the cheek, dissection within the subcutaneous plane is often preferred.

Skin or myocutaneous flaps are useful when direct closure is not possible. Flap depth is matched to the depth of the defect. Myocutaneous flaps consisting of orbicularis oculi muscle and overlying skin are the most versatile and often most useful option. They have the advantage of bringing with them their own blood supply as well as having the ability to supply vascular support to posterior lamellar (tarsal or conjunctival) grafts. Multiple configurations paralleling reconstructive techniques used in other parts of the body are possible and include advancement, rhomboid, and semicircular flaps (57). Upper and lower eyelid myocutaneous flaps are created similarly to those described for medial canthal defects. Horizontal incisions are made in the lid crease of the upper and subciliary in the lower eyelid. Tissue is then rotated horizontally and sutured in place. Transposition flaps can often be created from redundant upper eyelid tissue and used in reconstruction of lower eyelid and canthal defects.

When creating periocular myocutaneous flaps keep in mind the following guidelines: (i) create minimal horizontal and no vertical tension, (ii) hide incision in natural skin creases (e.g., eyelid crease or "crow's feet"), (iii) when advancing beyond the orbital rim transition to the proper tissue plane, (iv) anchor tissue to the periosteum not the soft tissue of the eyelid,

(v) overcorrect the position of the flap such that contraction does not cause eyelid distortion, and (vi) when operating on the lower eyelid, consider a tarsal strip procedure to correct any horizontal eyelid laxity.

When eyelid flaps are precluded either by the large size of a defect or the lack of redundant eyelid tissue, such as in a postblepharoplasty patient, soft tissue of the cheek or forehead can be utilized. Glabellar and midline forehead flaps were discussed in the section on medial canthal defects. The Mustarde cheek rotation is a flap that can cover large (greater than 75%) lower eyelid anterior lamellar defects. The flap is extended lateral to the palpebral fissure superiorly and laterally in a curvilinear fashion arching to the preauricular region. Undermining is initially in the suborbicularis oculi plane with a transition to the subcutaneous plane at the orbital rim, approximately 2.0 to 2.5 cm lateral to the canthal angle. This is continued until the eyelid defect can be closed without tension. The myocutaneous portion of the flap is used for reconstruction of the eyelid. Periosteal fixation of this myocutaneous portion adjacent to the lateral canthus with a permanent or slowly dissolving suture is essential. When combined with a posterior lamellar graft, the Mustarde flap can be used in full-thickness eyelid reconstruction.

Full-thickness skin grafting is useful for superficial defects and those too large for rearrangement of adjacent tissue. Principles regarding donor site choice are similar to those described for medial canthal defects. A few tips specific to eyelid grafts are as follows. When the pretarsal orbicularis oculi muscle has been lost, skin grafting may not provide adequate lower eyelid support. In such cases, additional lower eyelid support can be achieved with an upper eyelid myocutaneous pedicle flap placed over the tarsus. The remainder of the defect can be grafted. Alternately, a sling can be created similarly to techniques described under management of paralytic ectropion. Although anterior lamellar grafts can be placed over posterior lamellar flaps, due to limited blood supply, they cannot be placed over a posterior lamellar graft. This is discussed further with treatment of full-thickness eyelid defects. Lastly, Frost sutures or a temporary tarsorrhaphy can be used to limit eyelid retraction due to graft contraction. Frost sutures are permanent sutures passed through the tarsal plate at the eyelid margin, which are then taped or sewn opposite the reconstructed eyelid to the brow or cheek.

Full-Thickness Eyelid Reconstruction

Table 2 summarizes a generalized progressive approach to full-thickness eyelid defects. Repair depends on defect size and laxity of the remaining eyelid. Lacerations without tissue loss are closed primarily. Approximation of the eyelid margin is done in following manner. The tarsus is sutured in a vertical mattress fashion with the knot lying away from the cornea. The meibomian gland orifices mark the center of the tarsus. The anterior and posterior lash lines are then closed in a similar fashion. Depending on the surgeon's preference a 7-0 vicryl or permanent suture may be used. The three margin sutures are left long (2 cm) and secured to the adjacent skin. The proximal tarsus is then closed with multiple interrupted 5-0 or 6-0 vicryl sutures; the larger upper eyelid tarsus will require two or three and lower one or two additional sutures. Knots are positioned between the tarsus and orbicularis oculi muscle. The skin and muscle are then closed in a layered fashion.

TABLE 2 Approach to Full-Thickness Eyelid Defects

Estimated defect size (%)	Tension	Repair
0–25	None	Primary closure
25–50	Minimal	Canthotomy and cantholysis Approximation of margin
50–75	Moderate	Tenzel flap Approximation of margin
75–100	Maximal	Posterior lamellar flap Anterior lamellar graft or Anterior lamellar flap Posterior lamellar graft

Depending on eyelid laxity, defect up to approximately 25% can usually be closed primarily, without advancement of additional tissue. In larger defects, steps must be taken to relieve tension. The eyelid can be released from the lateral orbital rim with a canthotomy and cantholysis (described above with the tarsal strip procedure). This is often sufficient in eyelid defects ranging from 25% to 50%. The margin is then repaired identically to full-thickness eyelid lacerations without tissue loss.

When cantholysis does not sufficiently relieve tension, the next level of repair is a Tenzel flap. This flap is almost always sufficient for defects involving 50% of the eyelid and often in defects up to 75%. The first step is to perform a canthotomy and cantholysis, which is extended laterally with a superior arch for approximately 2 to 2.5 cm. Undermine the flap in the suborbicularis oculi plane. After extended laterally and undermined so that the margin can be closed without tension, the flap is anchored to the lateral orbital rim periosteum with a 4-0 vicryl suture. It is also important to approximate the lash line of the opposing eyelid to the epithelium of the reconstructed eyelid. This can be achieved with a buried 7-0 vicryl and superficial 6-0 fast-absorbing plain gut suture. Sufficient conjunctiva usually exists to cover the posterior surface of the flap. Occasionally a mucus membrane graft is necessary. The remainder of the flap is closed in a standard layered fashion.

Large defects involving greater than 75% of the eyelid require a complex approach. A combination of a flap and graft is usually used. Full-thickness grafts or combined anterior and posterior grafts have poor blood supply. Therefore, at least one lamella, either anterior or posterior, must be reconstructed with a flap. Anterior lamellar flaps and grafts are described with repair of anterior lamellar defects and do not differ when used for full-thickness defects.

The posterior lamella can be reconstructed with a free tarsal graft. An advantage of free tarsal grafts is that reconstruction is done in a single stage. In contrast, posterior lamellar flaps often require a second surgery. Tissue is harvested from the contralateral upper eyelid. Approximately 4 mm of tarsus should remain to prevent malposition or contour abnormalities of the donor eyelid. No suturing of the donor site is needed. The graft is sewn into place with an overlying anterior lamella flap (58).

When there is insufficient laxity of adjacent tissue for an anterior lamellar flap or healthy tarsus is not available for harvesting, a posterior lamellar flap is created. For large lower eyelid defects a Hughes flap is useful. This is an advancement flap created from the tarsus of the opposing upper eyelid. Similar to free grafts the inferior 4 mm of tarsus is left intact in the donor eyelid. The superior portion of tarsus is freed from overlying muscle. Dissection between Muller's muscle and conjunctive is extended deep into the superior fornix. The inferior cut tarsal edge is sutured with 5-0 vicryl sutures to the remaining posterior lamella of the lower eyelid. The tarsus can then be covered with either a full-thickness skin graft or myocutaneous flap. The conjunctiva bridge is incised after three to four weeks. Alternately, Hewes et al. described a laterally based upper to lower eyelid tarsoconjunctival transposition flap (59). This has the advantage of being a single stage procedure.

Large full-thickness upper eyelid defects are probably the most challenging of all eyelid reconstructions. Replacement of the tarsus with the patient's own tarsus is ideal. As mentioned above, free tarsal grafts from the contralateral upper eyelid can be used. However, healthy tarsus is not always available. Various tarsoconjunctival flaps have been described (60–62). They all have the disadvantage of requiring redundant adjacent tarsus from which to harvest. Due to its small size, lower eyelid tarsus has limited use. Although flaps can be created from remaining upper eyelid tarsus, a lack of tarsus inherent to upper eyelid defects usually precludes this. In short, posterior lamellar flaps are often not possible in reconstruction of large upper eyelid defects. When free tarsal grafts or flaps are not possible, a Cutler-Beard procedure can be performed (63). This can be used in large defects up to and including total loss of the upper eyelid. The initially described procedure resulted in little tarsal support. The procedure has been improved with modifications utilizing additional supportive tissue including ear cartilage or donor tarsus, sclera, and even aorta (64–66). The procedure is performed as follows. A flap equal the width of the upper eyelid defect is marked on the lower eyelid with its leading edge 4 mm below the inferior tarsal border. A full-thickness eyelid incision is made and extended inferiorly medially and laterally, creating a flap sufficient to fill the upper eyelid defect. The conjunctiva is separated, pulled under the bridge of lower eyelid, and sewn to the conjunctiva

of the upper eyelid. At this point, the surgeon's preferred tarsal substitute is fixed to the conjunctival flap. The myocutaneous flap is then similarly advanced under the intact lower eyelid and closed in a layered fashion, sandwiching the tarsal substitute between the conjunctival and myocutaneous flaps. The lower eyelid defect is not closed. Following six to eight weeks of healing, the eyelids are separated.

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4 Lip Reconstruction

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INTRODUCTION

The lips are an essential functional unit of the aerodigestive tract, relaying sensory information about ingested material while providing competence for oral continence. It is a prominent aesthetic focal point, with significant contribution to the appearance and appeal of the individual. Additionally, the lips assist in articulation and nonverbal communication via expressive cues.

Given the multifunctional role of the lips, ideal reconstructive efforts demand meticulous technique to accomplish aesthetic and functional restoration. While this goal may be limited by the inherent nature and extent of the patient's disease, this high ideal remains the goal for the dedicated surgeon.

HISTORY

The history of lip reconstruction finds among its earliest references citations of procedures performed centuries ago in India. The sacred texts of Susruta (circa 1000 B.C.) provides the first documentation of lip reconstruction. The Greek philosopher Celsus, in 25 A.D., described his closure of lip defects. In 1597, Tagliacozzi published his illustrations describing the use of pedicle tissue transfers from the forearm for lip reconstruction. Louis further advanced the field with his wedge excision and primary closure technique for small lip lesions. To address more complex midline defects, Diefenbach developed the concept of lateral advancement of cheek flaps. The lip switch was initially introduced by Sabattini in 1838, and later improved by Abbe. In 1838, Von Burow began performing triangular excisions to permit flap advancement.

The landmark nasolabial flap was described by Von Bruns in 1859. Estlander followed in 1872, describing a lateral perioral triangular shaped full-thickness flap for repairing lower lip defects. The twentieth century saw contributions from Gilles (1957) who described a fan-shaped flap for lower lip reconstructions. The innovative Karapandzic flap was published in 1974 and represented the first innervated flap reconstruction of the lower lip, with functional aims of dynamic competence and continence. In the same year, Hari and Ohmori published reports of microvascular free flap reconstruction of the upper lip (1).

ANATOMY

Oral competence is maintained by the orbicularis oris muscle. The lip elevators are the zygomaticus major, the levator anguli oris, the levator labii superioris, the zygomaticus minor, and the levator labii superioris alaeque nasi. The nasolabial muscles consist of the depressor septi muscle, the nasalis, and the nasalis transversus muscle. The muscles influencing the action of the lower lips include the depressor anguli oris, the depressor labii inferioris, the mentalis, and the platysma (2).

INNERVATION OF THE LIPS

The *infraorbital* branch from the maxillary division provides sensory innervations to the upper lip. The region of the oral commissure is served by the *buccal* branch of the mandibular division (V3). The *mental* branch of the mandibular division innervates the lower lip. Motor innervation to the lips and accessory muscles is via the facial nerve (CNVII). The buccal branch of the facial nerve provides motor innervation to the upper lip elevators and the orbicularis oris. The *mandibular* and *cervical* branches innervate the lower lip (depressors) and the platysma (3).

VASCULAR SUPPLY

The facial artery and vein provide vascularization to the lips via the inferior and superior labial arteries and veins. The vessels course medially, deep to the plane of the orbicularis oris muscle.

The landmarks of the nasal ala include the rim, base, nostril sill, and the columella base. The philtrum exhibits a characteristic groove and a lateral ridge. The “Cupid’s Bow” shape is the aesthetic ideal for upper lip contour. It features an apex, a tubercle, the base of the arch, and a mucocutaneous ridge.

CONDITIONS REQUIRING RECONSTRUCTION

Lip defects requiring reconstruction may be congenital or acquired. Congenital lesions include cleft lip and palate as well as lip pits and sinuses. Acquired deformities result from trauma or tumor resections.

LIP RECONSTRUCTION

Evaluation for surgical reconstruction of the lips should account for multiple factors. These factors include the age of the patient, gender, the location, and the extent of the defect. Extensive reconstructive procedures may not be appropriate for some patients. Elderly patients often possess dermocutaneous laxity sufficient to allow advancement, rotation, and transposition of a variety of flaps, allowing for less invasive reconstructive options. Sex specific aesthetic attributes demand efforts to approximate the natural ideal, such as restoration of hair-bearing skin to defects involving the beard and mustache areas in men (4). Restoration of the lips in females requires meticulous attention to recreating the profile to preserve the sensual appeal. Defects of the upper lip less frequently impair function but are aesthetically more challenging to recreate. The existence of restrictive or prohibitive comorbidities or contraindications should be considered in addition to age, sex, the location, and extent of the lesion.

The Rule of Thirds specifies that lesions less than 1/3 of lower lip or 25% of the upper lip should be treated by wedge excision with primary closure. Lesions 1/3–2/3 of the lips should undergo lip switch or local advancement flaps. Lesions greater than 2/3 of the lip should be treated by local or distant tissue closures (Tables 1 and 2) (5). The regional tissues should be assessed to determine the existence of lesions, evidence of injury (radiation induced), and the availability of appropriate tissue for use in reconstruction.

The incisions should be placed in congruence to the relaxed skin tension lines and aesthetic subunits defined by the anatomic architecture. These lines are vertically oriented on the lip, and then radially on the skin. Important aesthetic landmarks include the philtral crest, the philtral

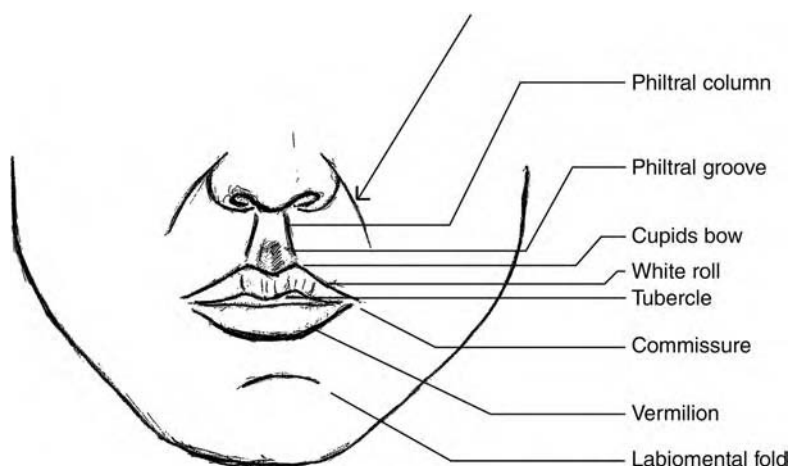
TABLE 1 Lower Lip Reconstruction

Defect Size				
—	< 1/3 of the lip	Primary closure	Commissure involved	Karapandzic flap 1 st choice Estlander flap 2 nd choice
			No commissure involvement	Abbe flap Karapandzic
	1/3 – 2/3 of lip	Sufficient lip tissue		
		Insufficient lip tissue		Bernard-Burow’s
—	> 2/3 of lip	Sufficient adjacent cheek tissue		Karapandzic for up to 80% or Bernard-Burow’s
		Insufficient adjacent cheek tissue		Distant / free flap

TABLE 2 Upper Lip Reconstruction

Defect Size				
< 1/3 of the lip	Central defect	Perialar crescentic excision		
	Vermilion intact	Nasolabial flap		
	Lateral	Primary closure		
	Central defect	Abbe flap with perialar crescentic excisions or Karapandzic flap		
1/3 – 2/3 of lip	Lateral	No commissure philtrum involvement	Abbe flap	
		Commissure involved	Estlander flap	
		Commissure and philtrum involved	Estlander flap with contralateral perialar crescentic excisions	
> 2/3 of lip	Sufficient cheek tissue	Central defect	Bernard-Burow's	
		Lateral defects	Ipsilateral Bernard-Burow's & contralateral perialar crescentic excisions	
	Insufficient cheek tissue		Distant / free flap	

groove, the vermillion, the white roll, the nasolabial junction, the lip-cheek junction, and the labio-mental groove (Fig. 1). The focus of reconstruction is the restoration of form and function. Functional reconstructions strive to preserve sensation, motion, sphincteric continence, and speech. The oral aperture should allow comfortable ingestion and, in some patients, permit the placement of dental prosthesis. The lower lip is of greater functional importance, whereas the upper lip is of greater aesthetic value. Essential principles of aesthetic reconstructions seek to restore the anatomic relationships to the preinjury state though limited by the context of the current injury. Evaluation of the lips in lateral view reveals that the lower lip lies posterior to the upper lip on Reidel's plane. In addition, the lower lip is gently overshadowed by the upper lip in the horizontal plane.

**FIGURE 1** Perioral anatomic landmarks.

POST-TRAUMATIC LIP RECONSTRUCTION

The principles of traumatic reconstructions involve extensive irrigation, minimal debridement with maximal preservation of potentially viable tissue, and exploration with identification of landmark layers and structures. Lesions amenable to primary closure are repaired by first approximating the white roll, the philtral columns, the mucosa-vermillion border, and the commissures with key fixation sutures. Once acceptable aesthetic alignment is achieved, the orbicularis is closed with absorbable suture, followed by closure of the mucosa. The final and third layer of closure is the skin, which is approximated with nylon or proline 6.0 sutures (Ethicon, Johnson & Johnson, Somerville, New Jersey, U.S.A.). Generally, these sutures are removed in three to five days; however in compromised areas such as irradiated or inflamed tissue the sutures may be removed at a later date. In children and selected adults, the use of fast absorbing sutures may be preferred.

Burn injuries to the oral region, particularly in the pediatric population, carry an associated risk of delayed bleeding from the labial artery. These lesions are generally managed initially in a conservative fashion, allowing for definitive demarcation of nonviable tissue and separation of eschar. The use of oral splints may diminish contracture deformations. Operative intervention is often required to recreate the oral commissures.

Neoplastic lesions most frequently involve the lower lips. Surgical excision of these lesions creates variable defects depending on the histology of the lesion and the extent of locoregional involvement. For cancer resections, it is essential to obtain histologically negative margins prior to performing reconstructive procedures.

LIP ANESTHESIA AND BLOCK TECHNIQUES

Effective regional anesthesia of the lips may be accomplished by blocking the infraorbital, the inferior alveolar, and the mental nerve (6). The infraorbital nerve is located in the midpupillary line in the infraorbital foramen 5 to 8 mm below the rim. An intraoral approach may be used to block this nerve (Fig. 2). The inferior alveolar nerve is located in the mandibular ramus. Infusion along the medial mandibular border is used to obtain anesthesia. The mental nerve emerges from the mental foramen located between the first and second bicuspid teeth. Injection at the canine root will establish anesthesia of this nerve. For more extensive procedures, general anesthesia may be selected.

When reconstructing the lip, it is essential to utilize full-thickness flaps to restore the normal anatomic relationships. Available tissue is recruited by various methods from loco-regional donor sites, including the cheek, the orobuccal surface, and the normal lip. It is critical to ensure mucosal lining of the commissure to minimize the development of contracture.

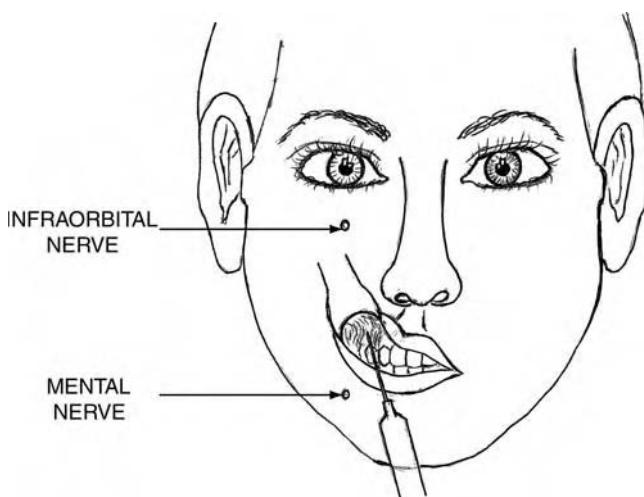


FIGURE 2 Intraoral approach to infraorbital nerve.

VERMILION

The vermilion of the lip is a modified mucosal surface with dense innervation and capillary vascularization. It functions as a sensory organ for pain, touch, and temperature. The anatomic borders of the vermilion are the mucosa-vermilion junction to the white roll. The vermilion is further divided into the “wet” and “dry” zones. The vermilion of the lower lip is often the site of premalignant lesions, such as leukoplakia and erythroplakia, which may be removed by shaving techniques. Extensive premalignant lesions or superficial carcinomas may be removed by total vermilionectomy.

Reconstruction of the vermilion requires the use of mucosal advancement flaps for optimal tissue match (Fig. 3). Small localized vermilion defects, such as notches or whistling defects, may be corrected by the creation of V-Y mucosal advancement flaps (7). This technique may also be used to recreate the tubercle of the upper lip. Limited areas of vermilion defect may be repaired by the creation of a transversely oriented vermilion lip switch flap. The donor site is primarily closed and the flap divided and inset later. Axial labial artery based musculo-vermilion flaps may be advanced to cover defects less than 30% of the lower lip. Repairs of the vermilion may produce contour defects in the area of the repair, and the option of replacing the entire vermilion should be considered for larger lesions. Following total vermilionectomy or “lip shave,” unipedicle or bipedicle single or multistaged procedures have been described for repair of the resulting defect. The simplest technique involves the creation of a relaxing incision in the anterior buccal sulcus with undermining of the flap anteriorly in a plane below the level of the minor salivary glands and above the orbicularis oris muscle. This essentially creates a bipedicle flap, which is then mobilized to the cutaneous junction and secured by fine plain gut or vicryl sutures. Variations of rotational and rhomboidal intraoral mucosal flaps have also been described to correct lip vermilion defects. Commissure-based buccal mucosal flaps were described by Tezel to restore complete lower lip vermilion defects (8).

Defects involving the muscle may be corrected by tongue flaps or modified Abbe flaps to provide the required bulk. Dorsal tongue flaps, introduced by Lexer in 1909, limit tongue mobility and are suboptimal aesthetic matches given the fine papillae (9). Some authors have described ventral tongue flaps, which produce an improved surface contour. The flap may be designed on the ventral aspect of the anterior tongue, incised, elevated, and mobilized anteriorly and inset into the lip defect. Division follows in 10 to 14 days and the tongue donor site is closed with absorbable sutures. The creation of this flap requires two stages and may be disconcerting to the patient. The mobile nature of the tongue presents a risk for flap dehiscence and crossing the dental incisor plane presents the possibility of inadvertent flap division. Jackson proposed the use of acrylic bite blocks cemented to the lower teeth (10).

The aesthetic subunits of the upper lip make reconstruction more difficult than the lower lip. Kawamoto designed a delayed transverse lower lip musculomucosal flap to correct mucosal and muscle defects of the upper lip (11). The flap consists of vermilion and a thin layer of muscle which is centrally based on the lower lip and tapered at its extension beyond the contralateral commissure. The flap is elevated and rotated upward 180° and inset into the upper lip defect. The flap is secured by sutures and divided and inset 14 days later.

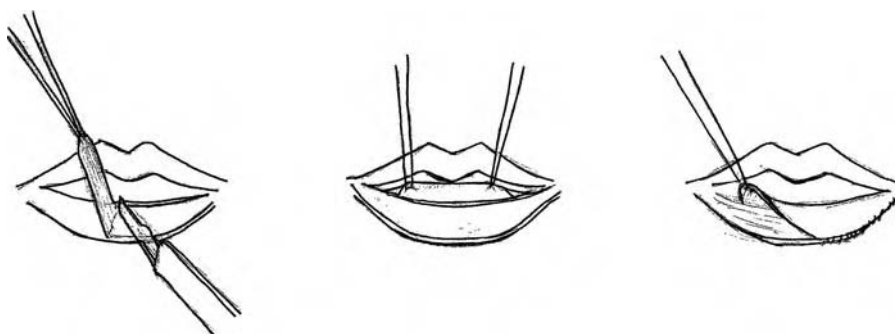


FIGURE 3 Vermilionectomy with mucosal flap advancement for lower lip vermilion reconstruction.

Intraoral mucosa is different from lip mucosa, and has a tendency to become dry. It is essential to use lubricants to keep the neovermilion moist.

MUCOSAL RECONSTRUCTION

Isolated defects of the mucosa involving limited areas may be corrected by the creation of simple V-Y advancement flaps. Triangular island variations of this technique have been described for lesions extending to the mucocutaneous junction. The triangle is based on the oral edge of the defect, and an incision of a "V" into the buccal sulcus allows elevation of the island flap on a submucosal pedicle. The flap is then advanced and closed in a "Y" configuration.

LOWER LIP RECONSTRUCTION

Defects involving only the cutaneous aspect of the lips may be closed by layered primary closure along the lines of relaxed skin tension. Areas too large for primary closure may be filled by full-thickness skin grafts. The defect should be configured to match the aesthetic subunit. The ideal donor sites include the posterior auricular and the supraclavicular areas. These grafts may heal with scarring and traction deformities on the adjacent lip margin. The use of bolsters is essential to minimize flap loss.

Full-thickness defects less than 30% of the lower lip may be closed primarily (Table 1). Excision of small lesion via wedge technique presents a defect favorable for this technique. A distinct advantage of this procedure is the approximation of like-to-like tissue. Prior to excising the lesion, the white roll and the vermilion borders should be identified by methylene blue marks to facilitate realignment. The key suture is placed in the white roll, then the muscle layer is approximated, and finally the mucosal layer is closed. "W" excisional patterns may be used for smaller lesions, permitting preservation of a maximal amount of viable normal tissue. Lesions with more significant depths of invasion may be removed by "V"-shaped incisions. Rectangular excisional patterns may be used for larger lesions, with bilateral advancement flaps permitting minimal tension repair. Excision of Burow's triangle of skin and subcutaneous tissue allows medial advancement of the flap to facilitate closure. Similarly, perialar crescentic or Webster-type skin wedge excisions may also be used. Single-barrel incisions may be used to excise and close paramedian lesions (Fig. 4). Shield-shaped or double-barrel patterns may allow adequate excision of midline lower lip neoplastic lesions while permitting minimal tension aesthetic closures.

NASOLABIAL

In 1859, Von Bruns described the nasolabial technique for reconstruction of large complex lip defects involving more than 60% of the lateral lower lip (12). An incision is created in the nasolabial fold extending from the alar base to the lateral commissure inferiolaterally. The flap is then elevated and rotated 90° and inset into the defect. The donor site is closed primarily, and the vermilion is recreated with mucosal flaps. Mobilization of bilateral flaps with midline approximation allows the recreation of the entire lower lip (Fig. 5). Subsequent modification of this technique produced a superiorly based flap constructed in a delayed two-stage procedure for repair of the lateral upper lip. Elevation of the flap above the muscular plane allows

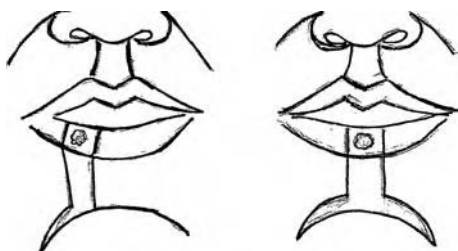


FIGURE 4 Single and double-barrel excision technique for lower lip lesion.

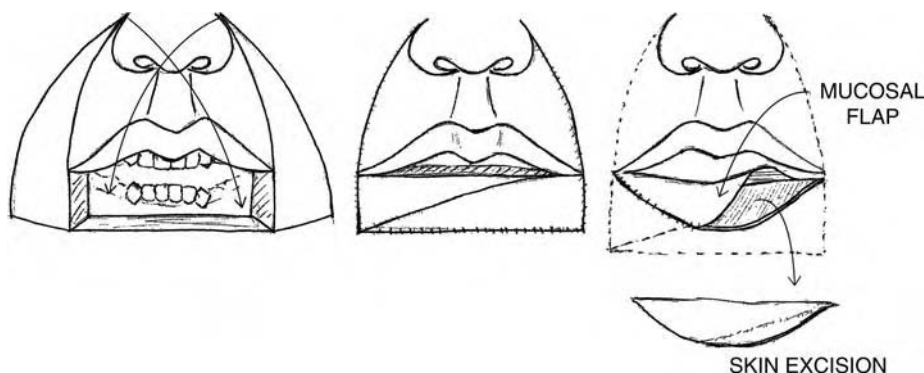


FIGURE 5 Nasolabial flap technique for lower lip reconstruction.

medial transposition of the flap. The donor site is closed primarily and the flap divided and inset in 14 days.

Issues involving this flap include pincushioning deformities of the flap margins. The donor site may exhibit asymmetry and possible color and texture inconsistencies in female patients. In male patients, the area may not demonstrate hair growth to match the contralateral side.

ABBE FLAP

The Abbe flap, first designed in 1898, may be used to repair defects involving less than half of the upper or lower lip. The lesion may be excised as a classic full-thickness “V,” a “W,” or wedge-shaped pattern. The use of this flap is restricted to lesions not involving the oral commissure, and in cooperative patients who will tolerate two weeks of lip apposition. The flap is designed on the opposite lip with an equal height and half the width of the defect. The flap should not exceed 3 cm, and the use of templates may assist with pattern creation. The flap is incised full-thickness on the nonpedicle side, and the pedicle position is noted. A pivot point based on the vascular pedicle is allowed a minimal protective muscular cuff. The flap is then rotated into the defect and secured via sutures. The donor site is primarily closed in layers. Again the white roll key stitch is placed first to ensure alignment, followed by muscular and mucosal layer closures. The patient postoperatively is maintained on liquids and soft diet with frequent oral rinses. The flap is divided three weeks later in a separate procedure. Prior to division, it is recommended that the viability of the flap be challenged by occluding the inflow via the pedicle to determine adequacy of graft site vascular incorporation. This procedure may be complemented by Burow’s triangle excisions in the case of rectangular flaps to allow optimal aesthetic closure. A potential risk of this procedure is avulsion of the pedicle in noncompliant patients.

ESTLANDER FLAP

The Estlander flap, first described in 1872, was designed to address defects 50% to 65% of the lip involving the oral commissure. This technique is essentially a modified Abbe lip switch flap based medially and rotated inferiolaterally to recreate the commissure. Unlike the Abbe flap, the use of this flap is confined to defects involving the commissure, and is performed as a single stage procedure without the need for subsequent flap division. The postoperative appearance is that of a “rounded” commissure lacking angular definition. There is a minimal risk of microstomia. The flap maintains muscular continuity and oral competence is preserved. However, distortion of the modiolus produces dysfunctional oral animation.

Gilles introduced a modification to correct the deformation of the oral commissure in Estlander flaps. The commissuroplasty is generally performed 12 weeks later and involves excision of a triangle of skin adjacent to the commissure. An angled incision is created along the vermilion border of the lower lip. The orbicularis muscle below is then divided horizontally at the neocommissure. Vermilion from the lower lip is mobilized superiorly to create a portion of

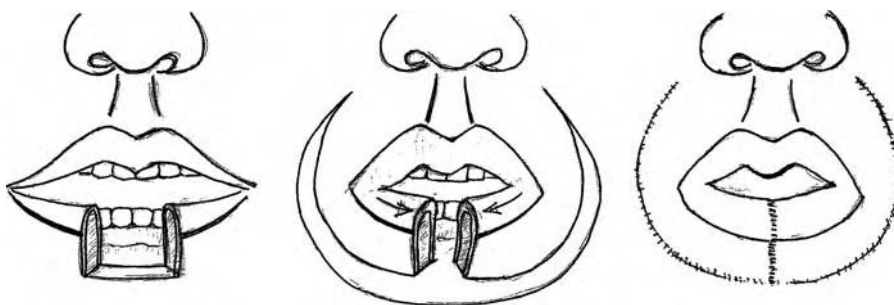


FIGURE 6 Karapandzic flap design for reconstruction of large lower lip defect.

the upper lip vermillion and commissure. The vermillion defect on the lower lip is filled using a buccal mucosal advancement flap.

KARAPANDZIC FLAP

This flap was developed to restore defects as large as 75% of the lower lip using a neurovascular intact perioral myocutaneous flap. The flap is designed such that the width of the flap is equal to the height of the defect. Transverse incisions are extended laterally from the base of the defect, curving laterally around the commissures and arching superiorly to the upper lips. The lateral fibers of the orbicularis muscle are bluntly separated longitudinally with meticulous dissection to identify and preserve the neurovascular supply to the orbicularis oris musculature. Bilateral flaps are raised superficial to the mucosa, with preservation of the buccinator (Fig. 6). The mucosa is then divided 1 to 2 cm laterally from the defect margin, then advanced and closed by approximating the corresponding layers on the medial flap margins. The flap can be reversed to repair defects of the upper lip. The specific advantage of the Karapandzic flap is the preservation of the native neurovascular supply, maintaining a sensate lip with intact sphincteric function.

The postoperative result is functionally good; however the aesthetic outcome maybe suboptimal and there may be reduction of the oral stoma aperture which limits use of this flap in patients wearing dentures.

GILLIES FAN FLAP

Originally described by Sir Harold Gilles, this flap was first designed as a unilateral fan flap to repair defects up to 50% of the medial lower lip. This was a modification of the Estlander flap with maintenance of the orbicularis oris integrity. Subsequent revisions of the flap design allowed its use in reconstruction of commissure defects and later bilateral designs allowed repair of total upper or lower lip defects. The flap design requires a full-thickness incision inferiorly, then superiolaterally around the commissures, and carried superiorly to the nasolabial fold in the domain of the upper lip. A back-cut is made medially and the flap pedicled on the superior labial vessels. The flap may be modified to a bilateral design for larger defects. The donor site closes primarily. There are several disadvantages to this flap. The full-thickness incision denervates the flap, rendering it insensate and dysfunctional creating problems with oral competence and continence. In addition, there is a reduction of the oral aperture and medial displacement of the commissure.

WEBSTER CHEEK ADVANCEMENT FLAP (MODIFIED BERNARD-BUROW)

This flap was designed to repair total defects of the lower lips. Bilateral arched incisions in the horizontal plane are carried laterally from the superior edge of the defect and extended through the commissure to the nasolabial fold (Fig. 7). Curvilinear triangular wedges (apex paranasal) of skin and subcutaneous tissue are excised lateral to the nasolabial fold to permit medial

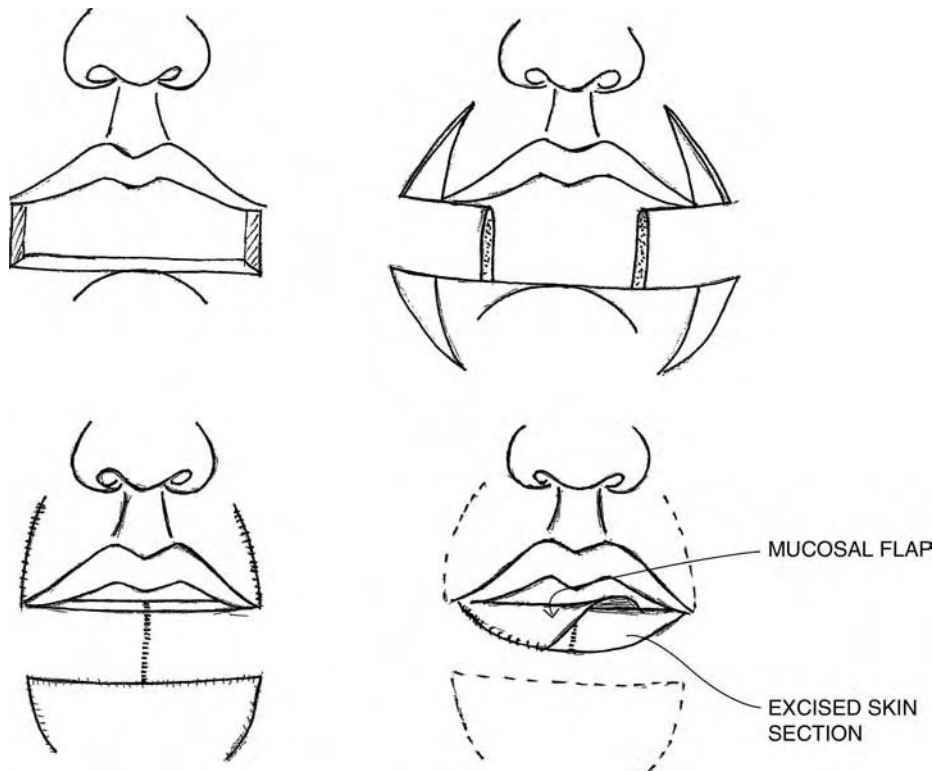


FIGURE 7 Webster modified Bernard-Burow chelioplasty with delayed mucosal advancement flap for lower lip reconstruction.

advancement of the laterally based flaps. Crescentic incisions extend bilaterally from the inferior lateral corner of the defect and arch inferiolaterally in the labiomentral fold similar to the “double-barrel” pattern. The medial margins of the flaps are approximated in the midline in anatomic layers. The vermilion is then reconstructed via mucosal advancement or delayed tongue flaps. The criticisms of this technique include poor competence of the reconstructed lower lip.

UPPER LIP RECONSTRUCTION

The complex architecture, and the aesthetic distinctions between sexes, creates a challenge in reconstruction of the upper lip (13). Fortunately, the upper lip is less essential to functional performance. Localized defects of the upper lip are best treated by primary closure. Larger defects involving less than 30% of the upper lip may be closed via the perialar crescentic techniques previously described (Table 2). Alternatively, an Abbe flap may be used for reconstruction. Defects involving the commissure may be closed using reverse Estlander flaps. For defects in the midline (philtrum), a reverse (upper lip) Karapandzic flap or bilateral perialar excisions can be used for closure of the defect. A more complex variation of this reconstruction incorporates a reverse (lower lip) Abbe flap to reconstruct the philtrum as an aesthetic subunit, with bilateral perialar crescentic flaps mobilized and approximated to the lateral margins of the neophiltrum. The incisional pattern is designed to mimic the natural philtral column. The reverse Abbe flap is then divided three weeks later. Previous descriptions of this reconstruction technique illustrate excision of the apex of the Abbe flap to permit a rectangular inset. A more anatomically precise reconstruction (not previously described) would involve preservation of the Abbe flap tip. This would require a shield or an oblique slope of the wound excisional margins, more narrow at the apex to complement the Abbe flap pattern. At the time of flap division, the relative excess at the pedicled end of the flap is inset to

recreate the natural everted projection of the tubercle. An inevitable consequence of the Abbe is that the arch formed by the pedicled base upon division, while desirable when lateral to the philtrum, is anatomically inappropriate in the midline. A third stage procedure would be required to reverse the arch and recontour the vermilion-cutaneous border to the cupid's bow configuration.

PERIARLAR CRESCENTIC ADVANCEMENT FLAP

The use of perialar crescentic advancement flaps can be used to reconstruct unilateral defects of the lateral upper lip which involve less than 30% of the area, although bilateral flaps may be used to repair defects of greater size. The defect is modified to a triangular pattern with the base superior along a diagonal long axis. A crescentic perialar pattern is outlined and excised, with broad undermining laterally in the cheek at the subcutaneous level. The skin is then advanced medially and sutured in to the defect, starting superiorly and progressing inferiorly. The mirror image may be performed on the contralateral side to repair larger lesions of the upper lip. This technique allows single stage aesthetic closure of large defect with minimal distortion of the alar base, the lip, or the oral commissure. Criticisms of this technique center on the effacement of the ipsilateral nasolabial fold in unilateral procedures (desirable in bilateral techniques). Like the superiorly based modified Von Burns flap, this perialar flap may have color and texture irregularities and in males may lack hair-bearing skin. In addition, there is a possibility of tension on the upper lip with decreased oral stoma aperture.

Large defects involving more than 65% of the upper lips may be repaired by using the reverse Webster modified Bernard-Burow chelioplasty. This procedure will recruit cheek tissue to reconstruct the lip, with skin and subcutaneous tissue excisions in the paranasal and inferior perioral regions to allow mobilization of the flap. The orbicularis remains intact, thereby maintaining functional mechanics. Large defects of the upper lip may also be repaired by a nasolabial orbicularis oris myocutaneous flap (14). An alternative is the bilateral nasolabial "gate" flap described by Fujimori (15). The nasolabial flaps are designed with the medial border in the nasolabial fold, and the crescentic wedges recruited laterally from the cheek tissue. The flaps are pedicled at the base, and the rotation point is at the commissure. Medial rotation of the flaps allows inset into the defect, with the flaps layered one above the other describing a diagonal approximation. The flaps are secured with sutures, and the donor sites are closed primarily. Following an appropriate delay period, a section of skin shaped like the lower lip vermilion is excised from the composite flaps and the defect is reconstructed using a buccal or tongue flap.

DISTANT FLAPS

Wound resulting from extensive trauma or extirpation may not be amenable to locoregional closure, and may require recruitment of distant flaps for closure.

VISOR FLAP

Visor flaps (bitemporal) can be used in men to reestablish hair-bearing tissue to an area of upper lip defect. The donor site is closed with a skin graft. Prior to division, the flap may be challenged by clamping. If it is viable independent of the pedicle inflow, the flap may then be divided and inset. The remaining flap can then be reinstated in the scalp by excision of the skin graft. Adjunct procedures include the use of mucosal flaps to reestablish mucosal and vermilion surfaces. An alternative to the hair-bearing scalp flap is the submental artery island flap, first described by Martin in 1993. This flap was recently demonstrated by Demir to restore appropriate match in reconstructions of the male mustache and beard areas (16).

FREE TISSUE TRANSFER

Harii and Ohmori in 1974 performed the first microvascular free-flap anastomosis for lip reconstruction (17). It is reasonable that future development may utilize this technique to repair

injuries, which exceed the availability of local tissue. Furuta (18), and later Camilla (19) independently described the use of composite radial forearm-palmaris longus tendon free flap for the reconstruction of extensive lower lip and chin defects. Walton et al. reviewed the multi-institutional experience with lip replantations post-traumatic injury and found that 10 of 13 patients had return of orbicularis function (20).

LIP AUGMENTATION

There are multiple approaches to lip augmentation. Surgical augmentation techniques using local V-Y advancement flaps have been described (21). Presently, the most popular techniques involve the use of autologous or exogenous material as filler. Bovine collagen has been available for use as injectable filler, and has been used extensively. The issue regarding its use concerns the potential for hypersensitivity reactions in 5% of patients. In addition, the product usually requires reapplication within six months for optimal effect. Acellular allogenic dermal grafts have been used for lip augmentation with satisfactory long-term results. Autologous fat grafts lack many of the negative aspects of foreign body filler materials (22). The immediate results are excellent; however much of the long-term graft viability is technique-dependent. Injectable hyaluronic acid derivatives, such as Hylaform® or hylan B [Biomatrix, Inc., Genzyme Biosurgery (Genzyme Corp), Ridgefield, New Jersey, U.S.A.] and Restylane (Q-Med Laboratories, Sweden) are available and have been used in facial and lip augmentation. Restylane, a stabilized, cross-linked hyaluronic acid genetically engineered by bacterial fermentation, has been used with promising results. A significant advantage of this product is that a skin test is not required. However, adverse reactions including redness, pain, and swelling have been reported in up to 5% of patients. Recently, the FDA approved the use of Restylane in facial augmentation. An alternative product, Artecoll, is comprised of polymethylmethacrylate ultra-smooth microspheres constituted with 3.5% bovine collagen and 0.3% lidocaine. Preliminary reports at this time indicate significant patient satisfaction, and the presence of the microspheres may represent a long-term augmentation. However, the formation of lumps and granulomas has been reported in some patients. There are anecdotal and editorial reports regarding the efficacy of this product; however, clinical experience with this product is reported from markets outside the United States because this product has not yet received FDA approval for use in facial augmentation (23).

The quest to refine surgical and minimally invasive techniques to reconstruct or augment the lips is an enduring testament to the esteem with which we regard them. In addition to their functional importance in nutrition, the lips possess an innate sensuality and are essential in self-expression and communication. In part, they help to define many subtle elements of our emotions and lend a visual clue to our complex character.

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5 Scar Revision, Dermabrasion, Local Flaps

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INTRODUCTION

Facial-scar revision presents a challenge to the plastic surgeon. In addition to the unsightly cosmetic aspects of the physical scar, the physician must also sometimes deal with the patient's emotional and psychological scars and expectations of the revision process.

This chapter addresses patient expectations, in addition to the wound and scar characteristics that the physician should consider when evaluating a patient for scar revision. Normal and abnormal wound healing are briefly discussed, but physical, pharmacological, and surgical management of keloids and hypertrophic scars are examined in greater detail. The chapter presents extensive information about noninvasive methods of camouflaging, or diverting attention away from scars. Alternative minimally invasive techniques using intralesional agents or soft-tissue fillers to minimize scarring are evaluated as well. A large part of the chapter is devoted to descriptions of surgical techniques for scar revisions, including dermabrasion, excision, and the use of local flaps to minimize the appearance of a scar. The advantages and disadvantages of these techniques are also reviewed. The final two sections briefly address postoperative care and complications.

SCAR

A scar is the fibrous tissue that remains after a wound is healed. The severity of scar formation is generally related to the amount of skin damage, healing time, the patient's age, and the location on the body. Although most scars fade as they mature over time, some will remain noticeable. Whether such a scar is acceptable or unacceptable depends on the degree of functional or cosmetic impairment and the patient's perceptions. The feasibility of scar revision is dependent upon the characteristics of the scar, as well as the patient's expectations.

When evaluating a patient with a functionally or cosmetically undesirable facial scar, the plastic surgeon must be prepared to deal with the technical, physical, and psychological issues in order to determine if the patient is a candidate for revision. In addition, the surgeon should explore the impact of the scar on the patient's life, examine the characteristics of the scar, and discuss the patient's expectations.

The age of the scar is an important first consideration. A scar may take one to two years to mature. If the injury is recent, the patient should be encouraged to allow adequate time for scar maturation before considering revisions. Erythema and raised borders are hallmark indicators of an immature scar.

The nature of the wound also influences the decision regarding timing of scar revision. The psychosocial elements associated with traumatic or self-inflicted wounds often manifest as severe emotional distress, and patients may go through a similar grieving process to death. The emotional sequence of grief, anger, denial, bargaining, and ultimately acceptance are common (1). The physical character of a minimally disfiguring scar may be deceptively disproportional to the significant emotional injury of the experience. The patient's expectations of scar revision are critical to the perceived success of the procedure. Surgery will not erase the scar; therefore, the patient who refuses to accept a permanent scar is a poor candidate for revision.

Once the patient's expectations and psychological/emotional status have been evaluated, scar analysis will determine technical feasibility and options for revision. The quality of a scar is evaluated by rating its color, width, depth, location, and orientation. Ideally the color of a scar should closely match that of the surrounding tissue. For optimal aesthetic outcome, the scar should be narrow, flat, and positioned between skin folds or wrinkles. A cosmetically

unfavorable scar lacks one or more of these characteristics. It may be hypo- or hyperpigmented, wide, depressed, or raised, or it may cross aesthetic subunits of the face.

NORMAL WOUND HEALING AND SCAR FORMATION

The ability of some wounds to heal normally with minimal scar formation while others form unsightly scars depends in part upon the healing process. The technique of wound closure can significantly influence that process. Primary wound closure encourages normal healing while eliciting the least amount of scarring. This “first-intention” closure is used for clean wounds that are immediately sealed by simple suturing, tape, adhesive gel, skin graft placement, or flap closure. The primary wound closure minimizes scarring.

“Secondary intention” allows wound healing via formation of granulation tissue, contraction, and sealing by epithelialization. This can lead to late wound contracture and hypertrophic scarring. Infected wounds, requiring tertiary or delayed primary wound closure, can heal with significant scarring as a result of poor blood supply and tissue destruction.

Wound healing is a process divided into four phases consisting of hemostasis, inflammation, proliferation, and remodeling.

1. *Hemostasis*: Immediately after wounding, basement membrane adhesive proteins, types IV and V collagen, fibronectin, and von Willebrand factor stimulate platelet aggregation (2). Activated platelets, growth factors, and other perivascular proteins initiate the clotting cascade with release of platelet-derived growth factor (PDGF) and arachadonic acid, ultimately leading to the production of fibrin via intrinsic and extrinsic pathways (2,3). Activated platelets and fibrin congeal to form a hemostatic plug. The platelets release chemotactic factors and arachadonic acid metabolites that attract inflammatory infiltrates into the wound. The arachadonic acid metabolites induce vasoconstriction (2–4).
2. *Inflammation*: Histamine and serotonin increase vascular permeability to polymorphonuclear leukocytes (PMNs) and fibroblasts, allowing diapedesis into the interstitial wound bed. Initially, the cell population is predominantly PMNs. After 48 hours, the PMN population gradually declines while monocytes (macrophages) increase to become the dominant cell type. The macrophages continue the wound debriding process for an additional 24 to 48 hours (5). Lymphocytes release mediators that stimulate and maintain the presence of macrophages during this period.
3. *Proliferation*: Known as the granulation phase, this features the formation of an extracellular matrix (ECM) populated by proteoglycans, fibronectin, hyaluronic acid, and collagen from fibroblasts. This superstructure provides a pathway for cellular migration (2,4). Macrophages stimulate neoangiogenesis and re-epithelialization. Granulation fibroblasts (myofibroblasts) pull the wound together in a process known as contracture (5,6). The wound fills in over the next seven to 10 days and continues to gain in tensile strength approximating 70% to 80% of uninjured skin over a period of at least six weeks.
4. *Remodeling*: During this phase of scar maturation, the population of macrophages and myofibroblasts slowly decreases. Wound vascularity is reduced until a relatively avascular mix of extracellular collagen and fibroblasts remains. During this stage, the collagen structure undergoes constant remodeling in an equilibrium phase wherein the collagen content is realigned without a change in collagen volume. The ratio of the collagen subtypes is also altered as the scar matures. Ultimately, over a span of one to two years, wound tensile strength increases to 80% of uninjured skin (7).

Numerous intrinsic and extrinsic factors exert an adverse influence on wound healing, thereby exacerbating scar formation. Age, infection, malnutrition, pharmacologic agents, radiation, diabetes mellitus, ischemia, and genetic predisposition can significantly increase the likelihood of prominent scarring (7). Patients at the extremes of age may have unfavorable scar formation. Young skin, which favors strong repairs, may have an exaggerated response to injury and form hypertrophic scars. An injury received in youth may stretch and become more apparent as the individual grows. In older patients, decreased fibroblastic activity can lead to delayed or inadequate healing with weak scar formation (8,9).

The inflammation response induced by infection triggers excessive fibroblast activity and interferes with wound healing (7). The deranged healing process results in increased local tissue destruction.

Inadequate oral intake, poor diet, altered metabolism, and malabsorption adversely impact the healing sequence and increase complications in hospitalized patients (10). Zinc, vitamin A, and vitamin C are essential for adequate wound healing (11).

Local or systemic corticosteroid therapy may impair the body's inflammatory response, which initiates the healing process. Exogenous steroid drugs inhibit cell growth and proliferation, decrease wound strength, and increase the likelihood of wound dehiscence. Fibroblast collagen production is inhibited, and the ability to fight infection is compromised.

Chemotherapeutic agents interfere with DNA and/or RNA synthesis, cell division, or protein secretion, thereby affecting the proliferative phase of wound healing. Patients who receive chemotherapy are systemically neutropenic and therefore susceptible to wound infection which further impairs wound healing.

Radiation reduces fibroblast proliferation, migration, and contraction and impairs the acute inflammatory response and granulation formation, resulting in slow or inadequate healing (12). This predisposes to wound infections and abnormal wound healing. In diabetics, hyperglycemia and the toxic byproducts of glucose metabolism decrease granulation and adversely affect collagen production and maturation, slowing the wound healing process (7).

Adequate perfusion is essential to healing. Insufficient vascular inflow will reduce delivery of oxygen and essential metabolic substrates required to support the cellular activity necessary for proper wound healing.

Finally, heritable disorders of collagen tissue, such as Ehlers-Danlos or Menkes kinky hair syndrome, cutis laxa, or osteogenesis imperfecta, impair wound healing (13,14).

ABNORMAL WOUND HEALING

"Overhealing" is an abnormal process featuring large, unsightly scars resulting from an exaggerated healing response to injury. Hypertrophic scars and keloids are forms of overhealing that are a consequence of excessive production or decreased absorption of ECM by fibroblasts, possibly stimulated by high cytokine levels (15). The abnormal scars may appear as early as four weeks or as late as two years after injury and are characterized by persistent hypervascularity and inflammation as well as abnormally increased lysyl hydroxylase activity. Scarring is more likely to occur in wounds that cross skin tension lines or in injuries located in thick skin or susceptible locations such as the earlobe, presternal, and deltoid regions.

Hypertrophic scars and keloids are found only in humans, occur in 5% to 15% of wounds, and are 5 to 15 times more common in non-Caucasians. Keloid formation is more common in Fitzpatrick skin types III–VII and is more likely to occur on the upper torso than on the face (16). Keloids not only extend beyond the original wound site, but also grow into neighboring tissue. Hypertrophic scars are bounded by the borders of the original scar. These scars commonly occur after thermal injury or as a result of excess tension or inflammation. The excessive tissue is typically red, raised, and pruritic.

Histologically, there are similarities as well as subtle differences between hypertrophic scars and keloids. Hypertrophic scars and keloids are distinguished from normal skin and scar tissue by their rich vasculature, high mesenchymal density, and thickened epidermal layer (17). Collagen fibers are found in swirls. Keloids contain a large amount of mucinous ground substance but have a lower fibroblast density than do hypertrophic scars (18).

Scanning electron microscopy reveals ultrastructural morphologic differences between keloids and hypertrophic scars (19,20). Hypertrophic scars have collagen fibers that are flatter and less clearly demarcated than those found in normal skin or scar tissue. The collagen fibers are fragmented, shortened, and loosely arrayed. Keloid ultrastructure is less organized, containing larger and more irregular collagen fibers with smaller interfibrillar distances than those seen in hypertrophic scars. The collagen nodule found in hypertrophic scars and keloids is absent from mature scars. The nodule is densely populated with fibroblasts and unidirectional collagen fibrils aligned in a highly stressed orientation (20,21).

There are biochemical differences between abnormal scars, mature scars, and normal skin. Collagen synthesis levels are three times higher in keloids than in hypertrophic scars and 20 times higher in keloids than in normal skin. Abnormal scars contain different proportions of collagen subtypes. The type III collagen in keloids is immaturesly cross-linked, indicating a pathologic process in which the ECM fails to achieve normal stability. Keloids contain 32% of type III collagen compared with 21% found in normal dermis. Collagenase activity is 14 times greater in keloids and four times greater in hypertrophic scars than in normal scar tissue. Levels of serum proteinase inhibitors α_1 -antitrypsin and α_2 -macroglobulin are increased in keloids (22). Therefore, keloid pathophysiology features not only increased collagen production, but also due to decreased collagen absorption.

The influence of growth factors on the formation of abnormal scars remains unclear. Fibroblasts extracted from hypertrophic scars demonstrate decreased proliferation in response to epidermal growth factor. However, their response to tumor necrosis factor- α (TNF- α) or PDGF is normal. Unlike normal fibroblasts, fibroblasts from hypertrophic scars show no increase in the rate of collagen synthesis when exposed to transforming growth factor- β (TGF- β) (21).

The management of keloids can be stratified into three categories: physical, pharmacologic, and surgical. Varying degrees of success have been reported for physical forms of treatment such as radiotherapy, ultrasound, cryotherapy, pressure, and laser. Most studies conclude that there is no role for radiation therapy alone in treating established keloids. External pressure has demonstrated efficacy in reducing abnormal scarring (23–25). There is insufficient data to support the use of laser therapy.

Radiotherapy has been used alone and in combination with excision to treat hypertrophic scars and keloids. The use of radiation as monotherapy is controversial because of the anecdotal reports of carcinogenesis following treatment (26,27). The response rate for radiation-treated keloids varies widely, from 10% to 94%, with a recurrence rate of 50% to 100%. Short-term follow-up studies (6 to 24 months) demonstrate that radiotherapy combined with surgical excision results in a response of 25% to 100%. A combination of surgical excision and perioperative radiation therapy reduces the keloid recurrence rate to 10% (28,29).

For refractory recurrent keloids, excision followed by reconstruction using a skin graft taken from the excised keloid plus immediate radiation therapy, has yielded good results. However, the long-term risks of radiation remain a significant concern (26,27). There is general agreement that radiation therapy should be reserved for adults and multimodality treatment failures.

Silicone gel sheeting used in combination with surgical excision or with intralesional steroids has shown good efficacy in the treatment of hypertrophic scars and keloids (30). In addition to minimizing scarring, the sheets also improve symptoms of pain and pruritis. This demonstrated efficacy using a combination of silicone gel sheeting and intralesional corticosteroids has led to its recommendation as first-line therapy for minor keloids and other abnormal scars.

The most commonly used intralesional steroid is triamcinolone. The action of triamcinolone and other glucocorticoids depends on the timing of their administration. When injected during excisional revision of keloids and hypertrophic scars, triamcinolone acts predominantly as an anti-inflammatory drug to retard the intensity of the wound healing response. For established lesions, the steroid is injected directly into the hypertrophic scar or keloid. The steroid tips the collagen balance from anabolism to catabolism. Some studies also suggest that steroids may suppress collagen gene expression (31). Dosages of triamcinolone used for injection range from 10 to 40 mg/mL. The higher concentrations are associated with more frequent local complications, including depigmentation, telangiectasia, dermal, and subcutaneous atrophy of normal surrounding tissue. Prudence dictates using the most dilute solution that will produce a response.

Test doses of varying strengths may be employed for a patient with extensive or multiple lesions. Local anesthetics can appropriately be used as diluents. In addition to their anesthetic effect, these agents inhibit both collagen synthesis and collagen secretion.

Other pharmacologic agents that have been used to treat keloids and hypertrophic scars include β -amino-propionitrile (BAPN), penicillamine, colchicine, retinoic acid, dextran sulfate, antineoplastic agents, adhesive zinc tapes, and silicone gels. BAPN is generally nontoxic and appears to exert a highly selective and significant lathyrogenic effect on the healing wound, possibly by producing poorly cross-linked collagen during the healing process. Colchicine

stimulates collagenase activity. Poorly cross-linked collagen is more susceptible than normally cross-linked collagen to digestion by tissue collagenase. Interferon- γ and interferon- α 2b have been studied in the treatment of keloids, but there is lack of evidence for their long-term effectiveness (32,33). Currently, there is no general consensus on recommendation of a specific therapy protocol.

Simple excision revision of a keloid scar is usually doomed to failure because the new wound is subjected to the same biochemical and mechanical forces that influenced the original wound. Excisional revision alone is an option only when a hypertrophic scar is clearly related to an antecedent wound infection or when the hypertrophic scar results from an incision or laceration that was originally perpendicular to the relaxed skin-tension lines. With these exceptions, surgical goals should be debulking the lesion or reorientation of the scar more favorably with respect to relaxed skin-tension lines.

Keloids frequently recur after excision despite the use of concomitant prophylactic therapy such as intralesional injection of corticosteroids. Indications for excision include failure of more conservative therapy, functional impairment resulting from the keloid, and aesthetic deformity significant enough to cause distress to the patient. The patient must accept the probability (45–100%) that the keloid will recur and that the new lesion may be worse than the original keloid. Complaints of burning and pruritis can sometimes be relieved with intralesional steroids or antihistamines.

NONINVASIVE MEASURES

Facial scars can be camouflaged with makeup, hair, or accessories such as a scarf. There are makeup artists who specialize in products and techniques for covering defects or scars, thus enabling patients to achieve an aesthetically acceptable image. Special cosmetics are available that blend uneven skin color, fill in small defects left by surgical sutures, and help correct facial asymmetries. Manufacturers include Cinema Secrets (Burbank, California, U.S.A.), Dermablend® (Ridgefield, New Jersey, U.S.A.), and M.A.C. (Make-up Art Cosmetics, Toronto, Ontario, Canada). These products are available for men and women and for individuals of different racial and ethnic backgrounds. Because water-based cosmetics do not stay on the skin and typically do not offer adequate coverage, these special cosmetics are formulated as thicker creams, silicone-blend, or wax-based products that give better coverage and create a more natural look (34). The cosmetics come in a wide variety of colors, and many are waterproof. Patients should be encouraged to explore these options.

Clothing color can draw attention to or away from a scar. Selecting the appropriate colors can minimize the appearance of skin discoloration, asymmetric facial features, and scarring by enhancing eye or hair color or skin undertone. Patients can consult color analysts or enroll in a course to help them select appropriate wardrobe colors.

Tattooing can minimize the appearance of hyper- or hypopigmented scars, by color blending to match the pigmentation of surrounding tissue. This option is reasonable when the scars are large or cannot easily be revised. Tattooing can also create lip lines, eyebrows, and eyeliner. The advantage is that the color is relatively permanent (34). The disadvantages are that the process is expensive and the pigment lasts about a year on grafted or scarred skin before it fades to a permanent blue gray. Tattooing should be done by a person who is familiar with scarred and/or grafted skin and is experienced in this niche area.

Hyperpigmented scars can be treated topically with pigment lighteners such as hydroquinone, which affects melanocyte metabolism by increasing the degradation of melanin while decreasing the formation of melanin (35). Scar contour, color, and texture may be improved by the application of silicone gel or sheeting. Scar compression can be used to reduce the size of excessive scar tissue.

MINIMALLY INVASIVE MEASURES

There are a number of methods, other than surgical revision, that can be used to cover, minimize, or elevate even large scarred areas. These techniques include intralesional agents, pulsed dye laser treatment, and soft-tissue fillers.

Soft-tissue fillers and implants can be used to minimize the appearance of a scar. An ideal soft-tissue filler is inexpensive, easy to use, biocompatible, nonpyrogenic, nontoxic, noncarcinogenic, nonallergenic, nonimmunogenic, and nonmigratory, and has long-term stability (36,37). Such an ideal implant has not yet been found. Biologic implants include autologous, allogeneic, and xenogeneic materials, such as bovine collagen, autologous collagen, allogeneic collagen, autologous fibroblasts, autologous fat, gelatin matrix, hyaluronic acid gels, preserved particulate fascia lata, and micronized AlloDerm®. Although these implants are biocompatible, their main disadvantages are reabsorption and lack of permanency. Bovine collagen, homologous human collagen, fat, and hyaluronic acid provide immediate but temporary augmentation for depressed or pitted scars. Treatments typically need to be repeated every three to six months. Currently, only biologic implants are available in the United States for soft-tissue augmentation. Semipermanent implants such as AlloDerm (banked human skin, LifeCell Corp., Branchburg, New Jersey, U.S.A.) and permanent implants of silastic, polytetrafluoroethylene, Goretex® (Flagstaff, Arizona, U.S.A.), and SoftForm® (Miramar, Florida, U.S.A.) can be used to elevate large areas. Alloplastic injectable soft tissue fillers are composed of silicone, Bioplastique (Bioplasty, St. Paul, Minnesota, U.S.A.), and polymethylmethacrylate (PMMA). Unlike biologic implants, alloplastic implants may provide permanent soft-tissue augmentation. Unfortunately, there are no alloplastic implants currently approved by the Food and Drug Administration (FDA) in the United States.

Bovine Collagen

Injectable collagen is a biologic implant consisting of reconstituted, purified, enzyme-digested bovine dermal collagen suspended in a phosphate-buffered saline with 0.3% lidocaine. Bovine collagen is used for the correction of facial rhytids and scars (e.g., postacne, post-traumatic, postviral, and postoperative) and lip augmentation. Deeply bound scars do not allow for infiltration of collagen. Bovine collagen injection is easily performed as a minor in-office procedure. It is readily available, reasonably priced, and administered with a minimal amount of pain. The main disadvantage of injectable collagen is that injections must be repeated every three to four months. Because bovine collagen may induce an allergic reaction, skin testing is mandatory.

Autologous Collagen

Autologen® (Collagenesis, Beverly, Massachusetts, U.S.A.) is an injectable autologous human tissue matrix, composed primarily of intact collagen fibrils (36,37). It is processed from the patient's skin, which is harvested surgically. Nerve blocks or local or topical anesthesia may be required during injections. At least three injections are required over several weeks to adequately augment a soft tissue defect adequately. Current clinical recommendation is to overcorrect at least 20% to 30% with each injection (38). The disadvantages include pain with injection, unknown duration of implant persistence, and the time required for harvesting and processing donor tissue. The advantage of autologen is that an autologous source eliminates the concerns for allergic reactions and viral transmissions.

Allogeneic Collagen

Dermalogen™ (Collagenesis, Beverly, Massachusetts, U.S.A.) is a suspension of injectable human tissue collagen matrix prepared from human cadaver tissue that has undergone extensive screening for viral and bacterial contamination (36). The injections are painful, and patients may require nerve blocks or local or topical anesthesia to tolerate them. Serial injections (usually three) over several weeks are required, with overcorrection of at least 20% to 30% recommended with each injection. Dermalogen can be used in patients allergic to bovine collagen. The disadvantages of Dermalogen include a lack of permanency and its relatively high cost.

Autologous Fat Injection

Autologous fat for soft-tissue augmentation has a high resorption rate and unpredictability. Atraumatic handling of the fat, use of larger suction cannulas and injection needles, and lower

vacuums seem to increase fat survival. Whether the fat should be washed prior to injection is controversial. Currently, there is no gold standard technique for autologous fat injection. The complications associated with the use of autologous fat include those associated with suction lipectomy and fat transfer in general. Edema, bruising, undercorrection, overcorrection, clumping, irregularities, fat necrosis, migration, and infection are among the most common complications reported. Disadvantages also include donor site morbidity, calcification of the injected fat, and unpredictable resorption depending on technique. The advantages of autologous fat are its abundance, no risk of disease transmission, and absence of allergic reactions.

Restylane/Perlane

Restylane (Q-Med Laboratories, Sweden) is an injectable form of naturally occurring hyaluronic acid obviating the need for a skin test for allergic reactions (39). Restylane is used for reducing wrinkles and folds, enhancing facial contours, and sculpting lips. The advantage of Restylane is that treatment often takes less than half an hour. Disadvantages include swelling, redness, pain, itching, discoloration, and tenderness at the implant site. Because Restylane is absorbed with time, treatments must be repeated in 6 to 12 months. Recently, Restylane has been approved by the FDA for use in facial augmentation.

Radiance

Radiance (BioForm Inc., Franksville, Wisconsin, U.S.A.) is a contouring agent consisting of injectable calcium hydroxylapatite suspended in gel (carboxymethylcellulose). It is used for lip augmentation and for filling of folds and lines, particularly in the lower half of the face. Because Radiance is a natural product, its use does not require allergy testing. Radiance remains soft when injected into soft tissue. Other advantages include correction lasting two to seven years. In comparison with collagen, fewer injections and less material are required for correction. One cubic centimeter of radiance can treat about twice as many areas as 1 cc of traditional collagen. The disadvantage is that the radiance injections are more painful than collagen injections. Radiance is not yet approved for use in the United States for these cosmetic procedures, although this product is currently being reviewed by the FDA.

Artecoll®

Artecoll® (Pulmon Medical, Scottsborough, South Africa) is an injectable soft tissue filler composed of 75% collagen (atelocollagen) and 25% PMMA microspheres (nonsilicone, carbon-based polymers) (40,41). When Artecoll is injected, the body encapsulates the PMMA microspheres with connective tissue, preventing phagocytosis and/or dislocation of the microspheres. The process is complete at three months. If additional correction is required, a small amount of Artecoll can be injected at that time. Artecoll can be used for correction of folds and wrinkles of the face, lip augmentation, acne scars, nasolabial folds, subcutaneous skin defects, chin or bridge of the nose, irregularities of the nose, and small facial or hand bone defects. Artecoll has several advantages. Treatment consists of a simple in-office procedure that can be completed quickly and conveniently. Because Artecoll is claimed as a permanent implant, its effects have been reported to last at least 10 years. The disadvantage of Artecoll is that it requires a skin test because the product contains collagen. In addition, greater skill is required during injection to prevent lumping under the skin. Delayed granuloma reactions to Artecoll have been reported and should be discussed with patients (42). Artecoll is contraindicated in patients with immune diseases, those who are susceptible to enlarged scars (keloids), or those with thin, loose skin.

Dermabrasion

Dermabrasion is used primarily for removing acne scars, rhytides, and surgical or traumatic scars. The technique uses abrasive materials such as aluminum oxide crystals, sand paper, acids, liquid nitrogen, scalpels, steel brushes, or a diamond braise on a hand drill for superficial resurfacing of the skin. Removing the epidermis and upper dermis smoothes uneven surfaces and allows the deeper layers to form new collagen and regenerate skin cells, thus creating continuity between the scar and normal tissue, thereby allowing the scarred area to blend into adjacent

tissue. Microdermabrasion, a gentler variation, can be used to polish skin. The technique produces a result similar to a chemical peel, but typically requires five or six treatments a week or two apart. Optimally, dermabrasion should be performed 4 to 12 weeks after surgery or wounding because collagen remodeling is very active at this time. The technique is particularly amenable to the revision of small scars in an office setting. Dermabrasion can also be used to remove a variety of skin lesions and blemishes.

The patient's skin tone, elasticity, and symmetry should be evaluated. Previous abnormal healing, scarring, telangiectases, pigment alterations, and bacterial or viral infections should be noted. Recent use of Accutane® and immunosuppressive drugs are relative contraindication given the possibility of atypical postoperative scarring. The physician should discuss types of anesthesia and ascertain that the patient understands the procedure and its limitations. Most importantly, the physician should ensure that the patient has realistic expectations of the outcome of the procedure. If the patient has a history of herpes simplex, acyclovir may be given prophylactically beginning several days before treatment and continuing until the abrasion is healed. Antiviral medications should be prescribed for any patient undergoing aggressive treatment, regardless of a history of herpes. The patient may also require treatment with skin lighteners, such as hydroquinone, kojic, or retinoic acid, prior to having dermabrasion. Moderate or aggressive procedures require topical, infiltrative, regional, or general anesthesia. Postoperative bleeding is rare. Topical tretinoin or systemic corticosteroids may be prescribed postoperatively. Pain is typically controlled with mild narcotic analgesics and usually lasts only one to two days. Pain of longer duration may indicate infection. Complications are uncommon. After having dermabrasion, the patient should be cautioned to avoid chlorinated pools for at least four weeks, active sports for as long as six weeks, activities that might lead to facial trauma for at least two weeks, and exposure to sunlight for at least six months. The patient should be advised to use sun block aggressively and continuously.

When used in scar revision, dermabrasion offers some advantages. It uses inexpensive equipment, leaves minimum thermal damage, and can be used to treat large areas in a short time. Disadvantages of dermabrasion are inherent in the process itself. Mechanical skin resurfacing can aerosolize skin, blood, and therefore viral particles that may be inhaled through a surgical mask. The technique has the potential for creating an unhygienic and potentially hazardous environment.

SURGICAL APPROACH

Excision

Primary excision is typically performed for scars 2cm or smaller. Ideally, the extramarginal incision should be placed inside an orifice, under the hair, at the junction of two aesthetic areas, or in or parallel to skin tension lines. The scar is removed as an ellipse of tissue. The edges of normal tissue are undermined and advanced to allow closure with minimal tension. Extensive areas of scar defects such as large skin grafted sites following burn reconstruction are best approached using serial excisions. An intramarginal incision is made and a segment of the scar is removed. The wound edges are undermined and approximated under moderate tension. The skin is allowed to stretch for 6 to 12 weeks. Then, the procedure is repeated until all of the scar tissue is removed. A broken line closure is usually used for the last excision to minimize scarring. An alternative approach is by tissue expansion followed by surgical excision.

Z-Plasty

Z-plasty is used to lengthen and reorient contracted or poorly placed scars. The procedure is most useful for correcting a linear incision that cuts across facial planes in a web-like contracted scar. This revision technique requires careful planning, because the degree of scar lengthening is proportional to the angle of the flap. The angles between the central and lateral limbs should be equal. Typically, this angle is 60°. A 60° angle extends the length in parallel to the common central limb by 75% (Fig. 1). It shortens or tightens the tissue in the perpendicular direction. The scar is excised to create a central limb. Two triangular flaps are formed by making two incisions, called lateral limbs, one at either end of the incision, thus creating three scars instead

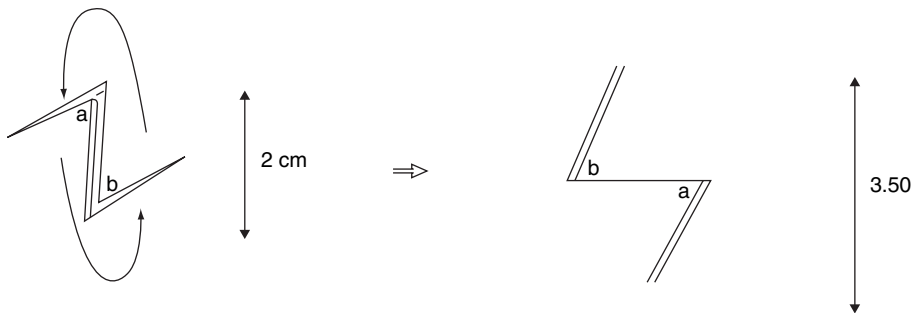


FIGURE 1 Z-plasty rearrangement designed on 60° flap angle to produce 75% gain in length along common axis.

of one. The flaps and margins are undermined to minimize tension, and the flaps are overlapped to transpose the excess tissue into areas with insufficient tissue. The transposition process reorients the scar by approximately 90°. Ideally, the lateral limbs should parallel favorable skin tension lines to minimize tissue distortion and protrusion. For long linear contracted scars, compound Z-plasty, serial Z-plasty, or multiple Z-plasty is recommended.

W-Plasty

W-plasty is a simple technique utilizing a series of small triangular flaps to camouflage longer scars, particularly if they are contracted or deeply tethered. The scar is excised and the triangles are incised. The wound edges are then undermined and the flaps are interdigitated. A two-layer closure is performed carefully to encourage eversion and reduce wound tension. The running W-plasty is a versatile technique that is useful for revising a variety of scars, including curved scars. A modified running W-plasty may be used to achieve scar lengthening.

Broken-Line Closure

The broken-line closure technique, a challenging combination of alternating geometric shapes such as squares, semicircles, and triangles, is useful for revising long linear scars. The new scar, composed of a series of short, broken lines, fools the eye by obscuring the linearity of the old scar. A carefully designed broken-line closure utilizes a variety of variably shaped flaps; triangular flaps are recommended for curved scars. Flap heights vary from 1 to 5 mm, with heights increasing as the distance from the ends of the scar increases. Flap width ranges from 3 to 5 mm. As many short flap segments as possible should lie parallel to favorable skin tension lines and as few as possible should lie perpendicular to favorable skin tension lines. Because the flaps must be interdigitated, the heights of flaps and their respective defects must be equal. After the scar has been allowed to heal for 6 to 12 months, its appearance can be further improved with dermabrasion.

Local Flaps

Local cutaneous flaps are designed immediately adjacent to or near the location of the defect. When classified by method of transfer, local flaps are divided into advancement, rotational (pivotal), and transposition (hinged).

Advancement Flaps

The advancement flap allows for a sliding movement of incised tissue in a straight line without any rotation. The flap is mobilized along a single vector to cover the primary defect. Classically, the length to width ratio of an advancement flap has been 1:2 allowing for advancement of the flap to a distance approximating the width of the flap (Fig. 2). Advancement beyond this may be performed; however, it should be noted that the tension of the flap may increase dramatically, causing the distal blood flow to be compromised resulting in necrosis of the leading edge. Advancement flaps are designed as monopedicle, bipedical, V-Y, or extended V-Y.

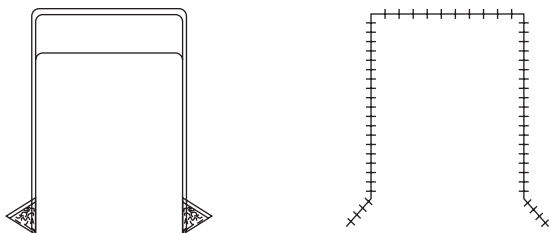


FIGURE 2 Advancement flap with single vector of displacement. Burow's triangle excisions facilitate inset.

The monopedicle flap works well on the forehead because it utilizes horizontal skin crease lines or the eyebrow region to hide a portion of the scar. The flap is raised by making two parallel incisions along the sides of the defect and then undermining a plane in the subcutaneous tissue. The flap is stretched into the defect. To facilitate advancement, triangles may be excised from the tissues adjacent to the base of the flap to provide the so-called pantographic expansion. Although backcuts or a small Z-plasty may be performed at the flap base to achieve greater advancement, these procedures must be performed with caution because they narrow the pedicle. The defect length to flap length ratio is made by wide undermining prior to parallel incisions made preferably in skin crease lines. The flap is inset with key stitches prior to the removal of standing cones.

The bipedicle flap works well in the forehead and brow where incisions can be hidden by skin creases or hair and is particularly useful for longitudinal defects. A disadvantage of this flap is the potentially long suture line.

The V-Y and extended V-Y flap utilizes a technique that involves moving a unique V-shaped flap into a defect with primary closure of the donor area leaving a final Y-shaped suture line configuration (Fig. 3). The incisions are made through the dermis and the subcutaneous tissues at the distal aspect. The proximal aspect is bluntly mobilized and left attached to the subcutaneous pedicle. A deeper dissection of the subcutaneous tissue only occurs at the distal end of the flap adjacent to the defect. This type of advancement flap is suitable in areas where mobile subcutaneous tissue is abundant with a rich blood supply. These flaps are ideal in reconstruction of defects of the cheeks, nasolabial areas, upper lips, and glabellar region.

The extended V-Y advancement flap is a modification of the V-Y advancement flap in which a transposition flap is added to one or both ends of a V-Y advancement flap that is larger than the defect. This transposition flap is subsequently advanced, and the extended portion is rotated on to the end of the flap to increase its length. Single and double extended V-Y advancement flaps have been used in the temporal and forehead regions and over the nose. These flaps have less subcutaneous fat and are less mobile than the cheek areas. The extensions on the V-Y flaps enable complex defects to be closed adequately. The rotation of the extended portion

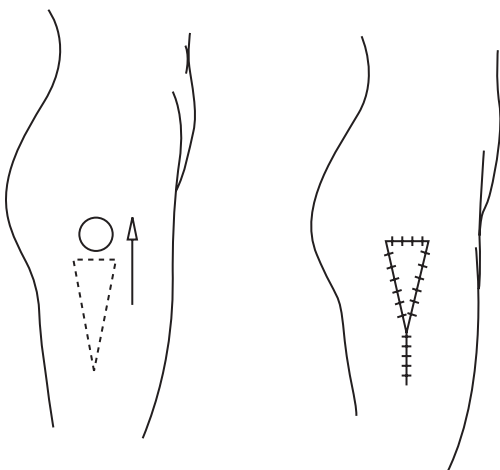


FIGURE 3 V-Y pattern for advancement of tensor-fascia lata flap to fill trochanteric defect.

of these flaps, however, may lead to the tissue distortion seen with other rotation and transposition flaps.

The Y-V advancement flap is a variation of the V-Y advancement flap, which may be used in serial fashion for release of scar contractures. The Y limb cuts across the scar contracture, and the adjacent V flap is advanced into the area of scar release. A Y-shaped incision is made initially, and the Y-V flap is pulled or stretched toward the area for supplementation. The flap augments the area of the common limb, while reducing the triangular area. Y-V advancement flaps are used to decrease the redundancy of an area by moving tissue away from the site. The technique is particularly useful for scar contracture release. Occasionally, relocating a free margin of a facial structure may improve symmetry.

Rotational Flaps

The basic rotational (pivotal) flap is curvilinear in shape and rotates around a pivot point near the defect (Fig. 4). This flap is designed immediately adjacent to the defect with one side as the advancing edge of the flap. As with all pivotal flaps, a standing cutaneous deformity (dog ear) that will develop at the base of the flap will have to be removed later. There are many advantages to the rotational flap. It has only two sides; therefore, both edges can be placed in borders of aesthetic units of the face, or into an aesthetic border and one relaxed skin tension line. The broad base of the flap allows a reliable vascular supply. It can be used to close triangular defects in general and scalp defects in particular. The flap is most useful for repairing defects of the cheek and upper forehead when the curvilinear incision can be placed along the inferior orbital rim or hairline. A disadvantage of this flap is that it must be quite large relative to the size of the defect. Ideally, the defect should be triangular in shape or should be modified into the shape of a triangle.

Rotational flaps are categorized as rotational and bilobed. The bilobed flap is an interpolated flap or pivotal flap that has a linear configuration. It is often used in the repair of facial defects. Classic examples are the vertically oriented midforehead flaps, such as median and perimedial flaps. These flaps are versatile in reconstruction of the midface, and particularly the nose, given their excellent vascularity, superb skin color, and ideal texture match. The popularity, high success rate, and reliability are primarily the result of a dependable axial blood supply. The frontalis muscle and fascia are included with the distal flap when more stiffness and bulk are required to fit defects of greater depth.

Transposition Flaps

The transposition (hinged) flap is linear or curvilinear in shape and is harvested at one site and transferred to a site immediately adjacent to the base of the flap, resulting in less wound tension and a scar in a more favorable axis. Transposition flaps are designed as rhomboid, bilobed, and trilobed.

Rhomboid flaps can be used at a variety of locations on the face. Geometry of the design is critically important. The single or Limberg flap is based on four equal sides with corresponding 60° and 120° angles. After careful design, there are three potential donor flaps from which to choose in order to appropriately align the final scar in an inconspicuous area and minimize distortion of the surrounding tissue.

Bilobed flaps are large rhomboid double transposition flaps that share a single base (Fig. 5). The flaps move around a pivotal point and invariably develop a cutaneous standing cone that

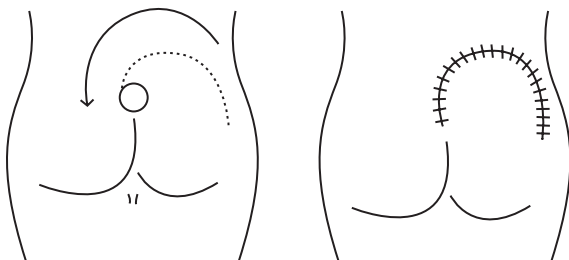


FIGURE 4 Rotation flap design for coverage of sacral decubitus defect post excision.

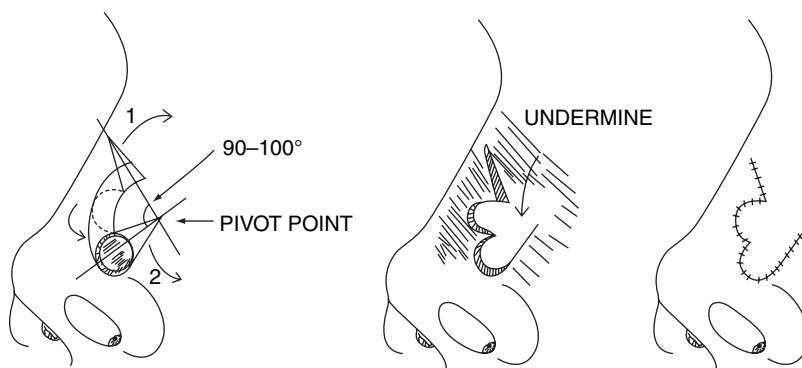


FIGURE 5 Bilobed flap design for lateral nasal defect. Note the undermining and the excised cutaneous segments 1 and 2 to accommodate inset.

is dependent on the arc of rotation. The primary flap is used to repair the surgical defect, and the secondary flap is used to repair the flap donor site. The secondary flap defect is then closed primarily. Final arcs of transposition of 90° to 110° are more optimal and result in smaller standing cone deformities. The primary use for this flap is in closing defects of the lower third of the nose. A disadvantage of the flap is that the resulting scar cannot follow skin tension lines in many cases.

POSTOPERATIVE CARE

The patient is usually sent home on the day of the procedure with prescriptions for a mild pain reliever and antibiotics if indicated. Written instruction regarding wound care should be provided to the patient. Pre- and postoperative nursing counseling should reinforce the instructions and assess the patient's understanding, competence, and potential for compliance. Sutures are removed five to seven days later and may be replaced with Steri-Strips® (3M, St. Paul, Minnesota, U.S.A.). Patients are cautioned to avoid direct sun exposure for two or three months to avoid pigmentary changes. If scar revision is necessary, dermabrasion may be performed at 6 to 12 weeks, but excision or scar modifications should be delayed for at least six months until the scar has matured.

COMPLICATIONS

Although complications are uncommon with local facial flaps, both physician and patient should be aware of the possibility of postoperative problems. During the preoperative discussions, particular emphasis should be placed on the likely complications common to the planned procedure. Pain on postoperative days 4 to 8 may indicate an infection, which can be managed by antibiotics and proper wound care. Immediate postoperative flap cyanosis can be the result of venous congestion. If excessive wound tension is the cause of the venous congestion, the physician should remove the suspect sutures. Multiple punctures with a sterile needle, heparin-soaked sponges, or application of leeches may also be beneficial for some flaps. Flap failure or flap loss is often the result of poor planning, suboptimal surgical technique, or pre-existing patient pathology. These complications can be greatly reduced by careful preparation. Hematomas and seromas increase the likelihood of flap necrosis. Cigarette smoking can increase the risk of flap loss and alternate design may be necessary in these patients. When necrosis does occur, it usually involves the distal tip and should be managed expectantly.

SUMMARY

Successful scar revision requires realistic expectations on the part of an informed, educated patient and mandates a critical analysis of the scar by the surgeon. The surgeon must then

discuss available options with the patient and select the most appropriate approach. Scars can be minimized with noninvasive, minimally invasive, or surgical methods. Keloids and hypertrophic scars are most effectively treated with pressure, intralesional corticosteroids, silicone gel sheeting, or a combination of radiation therapy and excision. Excision alone, unless used for debulking purposes, typically results in a higher recurrence rate.

Specialty makeup artists and color consultants can provide instruction and products that can help patients noninvasively minimize the appearance of scars. A variety of injectable (minimally invasive), commercially available, natural or synthetic soft-tissue fillers, and implants can provide permanent or semi-permanent correction of scars and aesthetic deformities. Multiple injections, over a period of several months, may be required.

If invasive measures are required, dermabrasion can be used to remove the epidermis and upper dermis and smooth uneven surfaces, allowing skin cells to regenerate. Invasive (surgical) procedures involve primary excision for small scars or serial excision for large scars. Other surgical techniques that minimize the appearance of scars include Z-plasty, broken-line closure, W-plasty, and running W-plasty.

Local flaps, advancement, rotational (pivotal), and transposition (hinged), can be utilized to cover large, depressed, vertical, or contracted scars. With good planning and attention to detail, flap failure and flap loss can be minimized. Advance preparation, diligent practice, and rigorous attention to patient education by the surgeon can result in minimal scarring and scar revision that is functionally and aesthetically pleasing to both patient and physician.

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6 Microsurgical Reconstruction of Craniofacial Soft-Tissue Defects

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INTRODUCTION

Severity of craniofacial defects is not always proportionate to the extent of soft-tissue loss. Some even smaller defects may lead to important functional and aesthetic impairment.

Exposure of the brain, sensory organs, and the upper respiratory tract are examples of primary indication for microsurgical reconstruction, but there are occasions when more extensive loss of soft tissue is followed by contour defects causing aesthetic impairment (1).

In this chapter, we focus on craniofacial reconstruction of soft tissue, excluding skin defects. These more rare indications need, in our view, microsurgical transplants as the best option for reconstruction. Even some bone defects may be reconstructed by soft-tissue flaps, following what was said by Longaker (2) that craniofacial reconstruction should be undertaken as a marriage between soft tissue and bone.

Deformities are mostly congenital, but other problems can be seen after tumor resection or following trauma (3). Most tumor resections include the cutaneous cover and are not dealt with in this chapter.

Choice of the transplant depends on the case and the experience of the surgeon, and this is not the place to discuss the value of conventional grafts and flaps compared to microsurgical flaps (4,5). There is no doubt, however, that with the expertise developed in microsurgery by plastic surgeons, the options for reconstruction that exist nowadays are numerous, particularly related to a wider choice of donor areas, superior aesthetic results, both on the recipient and donor sites (6).

Cutaneous flaps are generally thinner and more flexible, but they are primarily adequate for repairing linear and shallow defects. The muscular component is capable of filling spaces and cavities (7). Its high capillary density allows the prevention of infections and contributes to control pre-existing infections. In addition, there is the fact that it can be transferred as a motor unit to reestablish movement, especially facial expression. Muscle flap may also be used to offer a well-vascularized bed for simultaneous bone grafts or secondary bone grafts in subsequent procedures.

There is no flap that can be defined as ideal for all types of defects. Since the physical characteristics and, therefore, the distribution of body fat vary significantly from patient to patient, the cutaneous flap chosen must consider these individual situations.

As to the recipient site, it must be considered: the situation and distance of adequate recipient vessels, their caliber and the length of the vascular pedicle, the three-dimensional configuration of the defect (if it requires more coverage or volume or both), and the specific functional objective on the recipient site.

We should also consider the personal preference of the surgeon, the familiarity with a specific flap and the results he obtained with previous similar procedures.

Therefore, it is impossible to define a standard procedure for apparently identical situations. We present, in this chapter, our personal experience in some unusual clinical situations involving craniofacial soft-tissue microsurgical reconstruction.

- Facial hemiatrophy (Parry-Romberg syndrome).
- Replacing bone loss with soft tissues—maxillectomy, partial mandibulectomy, and mastoidectomy.
- Tissue replacement in Frey's syndrome after parotidectomy.

Facial Hemiatrophy (Parry-Romberg Syndrome)

The deformity, best described as progressive hemifacial atrophy, was reported by Parry in 1825, followed by Romberg in 1846. It is a rare condition, a slow and progressive atrophy of soft tissues on only one side of the face (95%, of all cases). There is no evidence of hereditary transmission.

Typically, it starts before 20 years of age and stabilizes after three to five years of clinical evolution. Some forms may be more aggressive. It affects subcutaneous tissue, muscle, fascia, and even bone, so the aesthetic impact of the deformity is variable, imposing a major challenge for the reconstructive surgeon. The picture is worsened by the sometimes "evolutionary" pattern of atrophy, dramatically changing the volume of the well-performed transplant. Skin is atrophic and may present changes in color, either hyper- or hypopigmentation, and some areas of alopecia.

Neurologic symptoms, such as headache, trigeminal neuralgia, nausea, and even convulsions, are sometimes present, and some authors pointed out that this association would be a sign of severity of the syndrome. Other authors called Romberg's a localized form of escleroderma.

The plastic surgeon should aim to restore a symmetrical facial appearance, as, in most cases, there is no major functional impairment for the patient. In most cases, psychological consequences of the aesthetic deformity are devastating.

The somewhat rarity and the diversity of involvement bring difficulties to the surgeon in establishing an average treatment for Romberg's disease. Long-term follow-up is essential for the correct evaluation of any form of surgical treatment.

It is understandable that almost every procedure at the disposal of the plastic surgeon has been proposed in the literature, from fat injections to dermal-fat grafts, local and distant flaps, and even fluid silicone injections, which were popular at one time but are not recommended anymore.

Vascular microsurgery made possible the transfer of large blocks of tissue usually needed in those deformities such as Romberg's, and the superior blood supply acts to control the atrophic forces, limiting the degree of recur.

Microsurgical reconstruction has been performed at the Division of Plastic Surgery at the University of São Paulo in Brazil since 1974 and already, in the second decade of experience, it became clear that some forms of soft-tissue atrophy might be improved by microsurgical transplantation.

The condition is not common, but working in an important reconstructive service in South America, we were referred a number of patients and gained some experience. Thirty cases were treated in last 20 years and 14 of them could be followed for a longer follow-up (more than five years).

The great omentum was the first donor-tissue option as it had the appeal of producing lesser deformity in the donor area (8). After a few cases, however, it was clear that the volume was not stable enough, as sometimes there was loss in other augmentation when the patient gained weight. Moreover, there was no good stability of the transplant in the subcutaneous pocket probably because the serosa cover does not heal well, and the sagging of the transplant made the aesthetic result unpredictable.

Muscle transfers were also used, but the donor-site defects are significant, and they are used only on rare occasions when the degree of facial atrophy was really impressive (Fig. 1).

Currently, our option has been the de-epitelized cutaneous flap, and flap mostly used, the parascapular (9). Some results can be seen in Figures 2 and 3. Although the subject is still controversial, some facts, in our view, could be accounted: In children, flap transfer should be performed earlier, before the deformity reaches its maximum point of atrophy. The transplant seems to improve the vascularity of the skin, an important point of the aesthetic result.

Microsurgical transfer may prevent the worsening of the atrophic condition if done in infancy. It is possible that this may be related to the increasing of vascular network on the affected area as there is a theory that the disease is a chronic form of ischemia, caused by neurological (sympathetic) impairment.

Cutaneous flaps are more consistent than other flaps in the long-term follow-up. Although they can enlarge with weight gain, liposuction may help. The dermis acts as fixing tissue, better

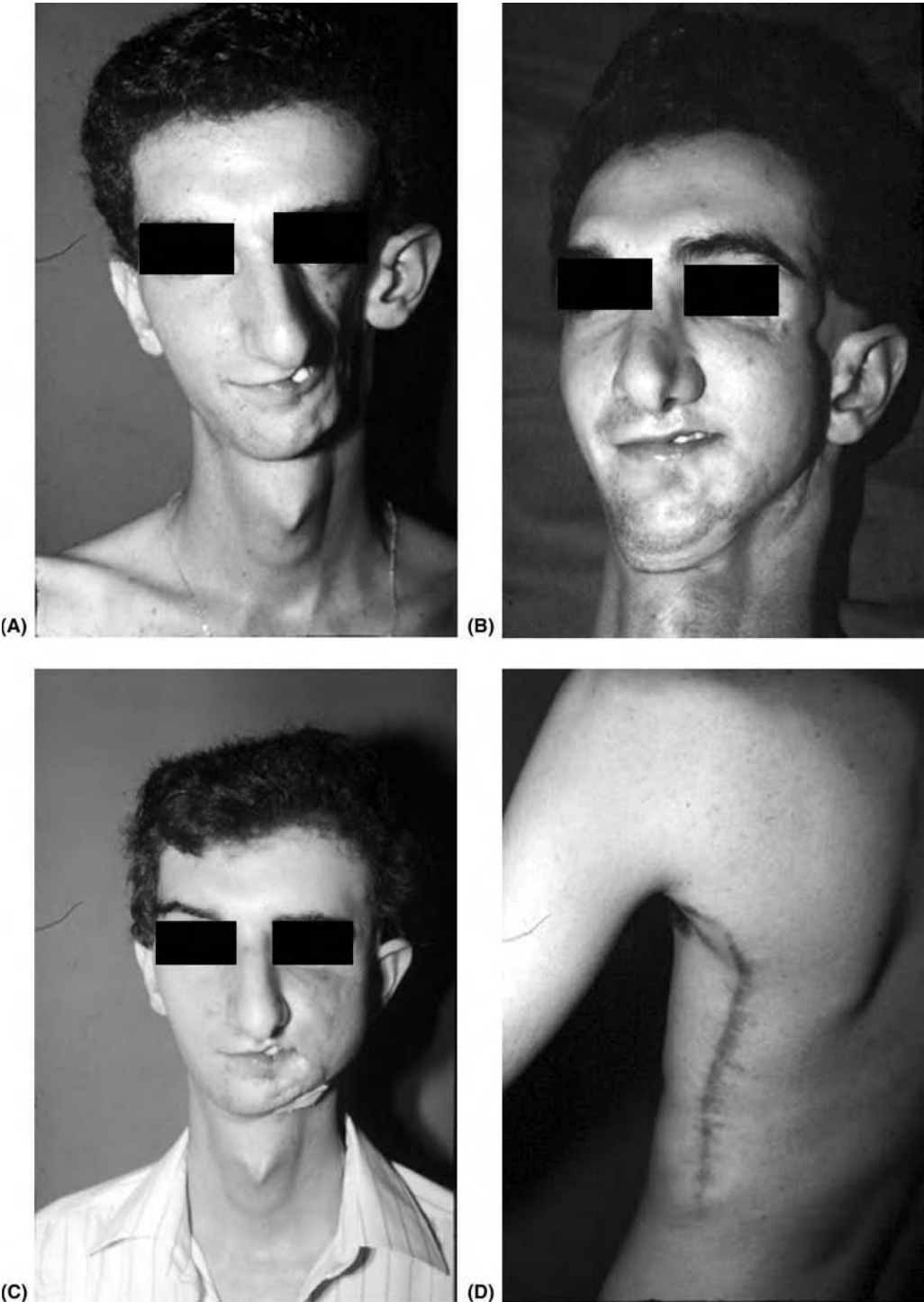


FIGURE 1 (A) Romberg's disease, preoperative condition. (B) Postoperative result of latissimus dorsi musculocutaneous transplant after one year. (C) Postoperative condition after two years. (D) Donor area.

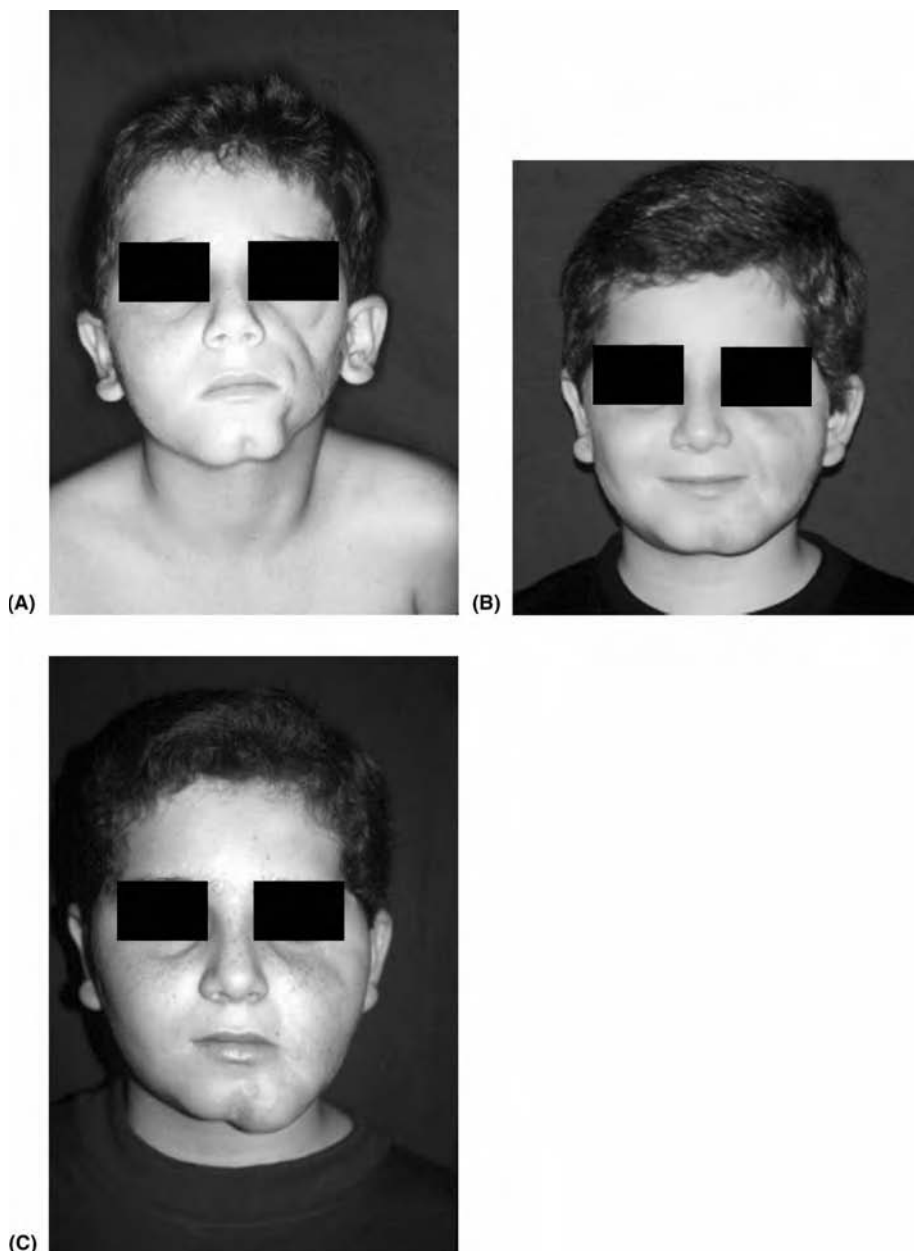


FIGURE 2 (A) Romberg's disease on a child, seven-year-old, preoperative view. (B) Postoperative result after four years—de-epithelized scapular flap. (C) Postoperative after eight years and two defatting procedures. A hemifacial suspension was also performed.

than omentum or muscle. Options for donor area are the scapular, groin, or, more recently, thigh flaps. Aesthetic concern in the donor area is still a problem. Many revisions are to be expected, and the patient should be prepared for them in the long-term follow-up. Those include liposuction, lipectomy, facial suspension, and scar revision. Fat grafts or injections are not indicated for more extensive deformities, and the result is usually temporary. A few reports claimed improvement with fat injections, and we used them only as complementary procedure.

Complications are rare as the vascular anastomoses are usually done on the normal facial vessels. Hematomas are frequent but not especially difficult to treat. Unreal expectations should

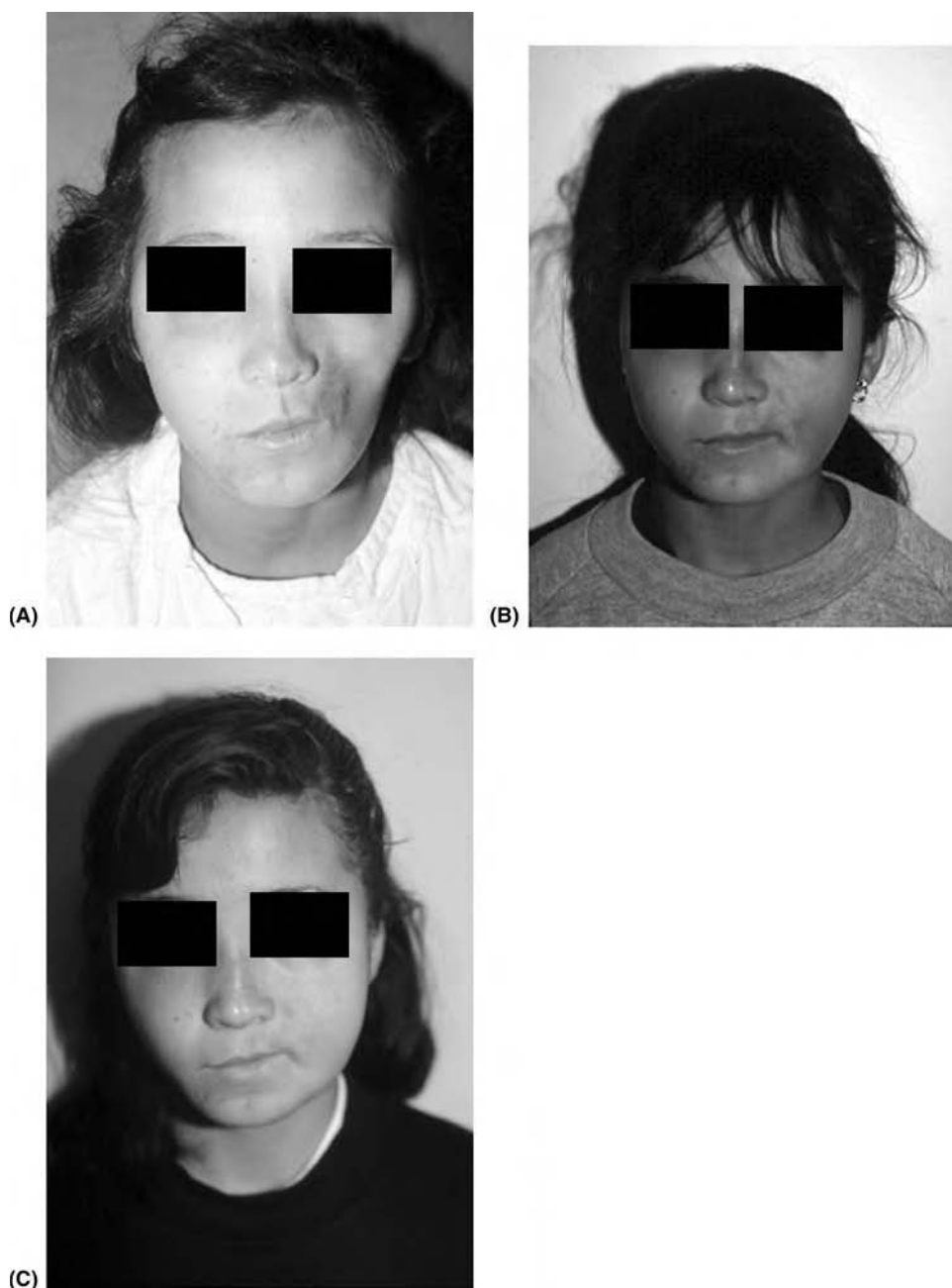


FIGURE 3 (A) Eight-year-old girl with left-side Romberg's, preoperative. (B) Postoperative after de-epithelialized scapular flap. Two years of follow-up. (C) Postoperative condition after eight years of follow-up, one revision with suspension.

be dealt with, even with help of specialized colleagues. In fact, the procedures are extensive (reconstructive), but the indication is for psychological improvement, and so often the patient expects the result to be comparable to what we usually call aesthetic surgery.

Maxilla

Maxillary defects affect the orbital floor, the nasal passage, the palate, and projection of the medial third of the face (10).

The flap should fill the maxillary sinus, support the eyeball, keep the nasal passage open, and separate the oral cavity from the nasal cavity, reconstructing the palate.

Ideally, the flap chosen should provide a cutaneous surface for the nasal passage and for the palate and should have enough volume to fill the maxillary sinus and keep the eyeball in its normal position (11).

In the cases where the orbital floor is preserved, we prefer to use the lateral arm or forearm skin flap. The cutaneous surface is folded to allow reconstruction of the palate and the lateral wall of the nose. A strip of the flap is deepithelized in the transition area between the oral and nasal cavity.

Mandible

Mandibular defects longer than 7 cm that involve the anterior arch are best repaired with vascularized bone transplants. Defects behind the medial third of the mandible and of the ramus can occasionally be repaired with soft-tissue flaps. The rectus abdominis muscle flap can fill this region, preserving the facial contour, and provide stability to the remaining mandible.

Frey's Syndrome

Unilateral gustatory hyperhydrosis was described in 1757 by Duphenix, and in 1847 by Baillarger. Frey related the physiologic phenomena (1923) and used the term "auriculo-temporal syndrome." The disease is also known as Baillarger's syndrome, Dupuy's syndrome, Frey-Baillarger syndrome, von Frey's syndrome, gustatory flushing, and auriculotemporal syndrome.

Frey's syndrome is characterized by increased temperature, redness, and sweating in the malar region, between the corner of the mouth and the ear, which begins minutes after food when a strong taste is ingested. Generally, only one side of the face is affected. The production of saliva in the parotid is controlled by autonomic nerve endings that are severed when this salivary gland is removed. These nerves grow back during the recovery period and form abnormal connections with sweat glands that are present in the overlying skin. When certain foods are eaten (salty or bitter), thought about, or talked about, the nerve impulses generated in the autonomic fibers and misdirected stimulate the blood vessels of the skin and the sweat glands instead of salivary flow. The result is facial redness and sweating.

Frey's syndrome is a common result of parotidectomy. The severity of the clinical symptoms ranges from a small area of redness to profuse sweating. Redness is prevalent in females and sweating in males.

Various treatments may be recommended:

- Topical application of antiperspirant.
- Topical application of "drying drugs" like scopolamine.
- Tympanic neurectomy.
- Placing tissue between the skin and the parotid region, which forms a barrier between the local nerve endings and the sweat glands of the skin.

We have used free muscle flaps, the gracilis, and the rectus abdominis for reconstructions immediately following total parotidectomies or in patients with severe Frey's syndrome. This offers a well-vascularized environment capable of protecting and favoring recovery of the dissected facial nerve branches. They preserve the facial contour and provide satisfactory esthetic results. The symptoms of Frey's syndrome disappear or are at least significantly reduced.

Mastoidectomies

Mastoid resection exposes extensive areas of bone surface and even the meninges. The cutaneous lining can be spared, but the fine skin in contact with aerated bone and/or the cephalic membrane does not offer adequate protection and predisposes the area to the appearance of chronic ulcers, persistent drainage, and meningitis (12). This condition is aggravated by radiotherapy.

Free muscle flaps are used to fill the defect, with or without the need of skin coverage. The esthetic and functional results are generally satisfactory. The external ear is kept in position and the cervicofacial contour is preserved. In this case, we recommend the rectus abdominis or gracilis muscle flaps.

If the skin defect is also extensive, we prefer the use of myocutaneous flaps like the anterolateral thigh flap, which uses part of the vast lateral muscle, and the myocutaneous rectus abdominis flap.

The facial nerve is often sacrificed during the mastoidectomy in order to reach the cancer-free margins. Treatment consists of interposing nerve grafts between the proximal trunk and the main branches (zygomatic and buccal), microscopically sutured. In patients who have not undergone reconstruction, this nerve graft rests between the slightly vascularized bone surface of the mastoid and the fine skin that covers this region. The reduced blood supply compromises the integration of the graft and, consequently, nerve regeneration. Placement of the free muscle flap between the nerve graft and the skin offers a more favorable environment for the recovery to progress satisfactorily. This muscle flap can also be folded to cover the entire section of the nerve graft. This method protects the area and minimizes the effects of radiotherapy (13).

Recipient Vessels

Choosing the correct recipient vessels determines the success of the microsurgical transplant. In addition to the proximity of these vessels to the defect, we must consider how they look to the naked eye and under a surgical microscope. The blood flow is also evaluated. The most used recipient arteries are the facial artery, superior thyroidal artery, and superficial temporal artery. The most used recipient veins those that follow said arteries (venae comitantes). In less common situations, any branch of the external carotid artery and vein draining into the internal jugular or external jugular are used. Vein grafts are used in the absence of an adequate recipient vessel in the region (14).

In patients submitted to radical neck dissections, we prefer to use contralateral cervical recipient vessels. Radiotherapy alone is the greatest risk to the success of microsurgical implants in our series. That is why recipient vessels from nonirradiated areas are preferred. We have used the internal mammary vessels, with and without vein grafts, in late reconstructions when the patient was submitted to radical neck dissection and bilateral radiotherapy.

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7 Hair Transplantation

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Whether hair transplantation is used for reconstructive or aesthetic cases, the single major advance in the last decade has been the transition from large, unnatural, unsightly hair grafts, to small, natural-appearing grafts containing one to three hairs (1). There have been many other advances in hair restoration in the last 10 to 15 years, but this one simple fact, going from large to small grafts, is by far the most significant (2).

Hair is frequently relegated to a less important status in either reconstructive or aesthetic surgery, yet compared to many other procedures, it may give some of the most dramatic and rewarding results. The scalp, the eyebrows, as well as the bearded areas in men are all critical components of the anatomy of the head and neck area. Whether due to trauma, birth defects, or natural evolution of the aging process, hair and hair loss play an important role in the appearance of the human face and scalp. This chapter discusses the evolution of hair transplantation to its present state, the surgical steps performed in the process of hair restoration, and provides examples of cases where hair restoration is useful in both reconstructive and aesthetic situations (3,4). Another important fact in hair restoration is whether the patient is a primary or secondary case, in either reconstructive or aesthetic situations. Primary cases usually entail simpler procedures, while secondary cases, either reconstructive or aesthetic in nature, often require careful analysis. Frequently, the original procedure may need significant modification or even a total revision when dealing with secondary cases (5–7).

Whatever the surgical situation, whether primary versus secondary, or reconstructive versus aesthetic, an ideal result in hair restoration should be as natural appearing as possible, avoiding the artificial results frequently seen in the past.

Since results with large plugs were so mediocre in the past, many surgeons used complicated flaps and scalp excisions as an alternative (8–11). Although hair-bearing flaps could move large amount of hair in a single stage, these procedures frequently failed, to give an ideal natural-appearing result (Fig. 1). In many situations, the pendulum has swung back to using hair transplantation because small grafts can be used in a multitude of clinical situations, often giving superior results compared to complicated flaps.

In order to create the most natural result possible, the surgeon needs to understand the normal anatomy of hair in the head and neck area. This anatomy relates to the characteristics of the human hairline, as well as of individual hairs. The anatomy of individual hairs varies according to color, texture, density, and straightness versus curliness. Curly hair, for example, microscopically, is oval on cross section, while straight hair tends to be round on cross section. Also, hair grows at different angles depending upon its location on the scalp and face. Eyebrow hair, for example, grows at a very acute angle to the skin. Hair along the frontal hairline of the scalp is angled anteriorly, while in the temporal area, it grows slightly forward and downward, and in the occipital area it grows downward toward the back of the neck. Therefore, attention to both the design of the hairline and the individual hairs composing the hairline are important.

In creating a natural hairline in both reconstructive or aesthetic settings, certain principles need to be followed. Unlike individual patient characteristics such as hair color or texture, which are out of the surgeon's control, the design of the hairline is within the surgeon's control. The hairline should be at least 8 to 10 cm above the glabella if not more. In male patients, the fronto-temporal angle should be maintained or if not present, it should be created. This is the angle that is formed by the junction of the frontal hairline as it meets the temporal hairline. In adult males, it should make an acute angle projecting posteriorly (Fig. 2). While in women and young males, this angle is usually rounded off. The other important component in a natural



FIGURE 1 Patient had a Parieto-temporal flap at a young age and then proceeded to lose the hair behind the flap. This case demonstrates the progressive nature of hair loss and the problem of creating an overly dense frontal hairline with an anteriorly placed flap.

hairline is irregularity and feathering. Perfectly straight hairlines look artificial and hair along the frontal hairline should be fine and made up of small single hairs (12,13).

Another important variable associated with hair is color contrast. As a principle, the less the color contrast between the transplanted hair and the skin, the more natural appearing is the result with irregularities being less noticeable. Light hair on light skin and dark hair on dark skin are good examples where there is very little color contrast. However, when hair and skin differ greatly in color, such as blonde hair on dark skin or dark hair on light skin, then any technical imperfections are far more noticeable.

Patients who are candidates for hair transplantation can be divided into categories. These categories include androgenic alopecia in men, androgenic alopecia in women, post-cosmetic surgery patients after facelift or forehead lift, postsurgical or traumatic hair loss, in either the scalp or eyebrows, and finally, congenital absence of hair. By far and away, the majority of people undergoing hair transplantation today are men in their late 20s to early 60s with male pattern baldness.

Androgenic hair loss can be seen in both men and women. In these individuals, androgens reduce both the growth rate and hair shaft diameter in susceptible areas of the scalp (14,15). In men, typically, the hair follicles in the frontal and crown areas of the scalp are the first and most likely affected by androgenic alopecia.

In order to create as natural result as possible in men with androgenic alopecia, five fundamental concepts need to be followed. The first is creating an irregular feathered hairline using small grafts. The second is creating a frontal temporal angle. The third is an age appropriate hairline at least 8 to 10 cm above the glabella. High hairlines tend to look more natural than low, especially as the individual ages. The fourth is creating irregularity and asymmetry. Symmetry may be an excellent goal in other areas of surgery, but not in hair transplantations. A perfectly straight, symmetrical hairline looks artificial. The fifth and final component of creating a natural hair restoration requires the use of small, natural-appearing grafts, usually containing one to three hairs per graft. These five surgical precepts need to be applied in conjunction with related factors such as the patient's age, amount of available donor hair, and extent of hair loss. It must always be remembered that androgenic alopecia is unpredictable and progressive. What may look good in patients in their 30s may not when a patient turns 60 (Fig. 3).

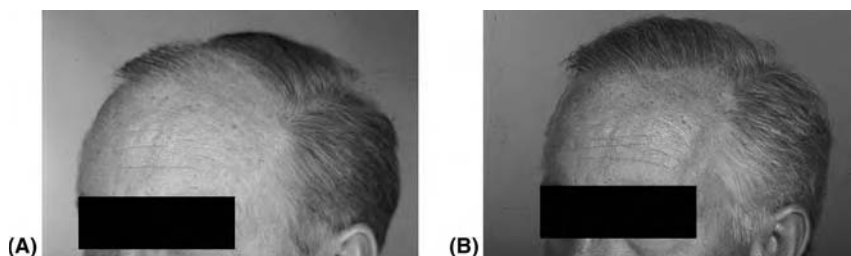


FIGURE 2 (A) Preoperative oblique view of 60-year-old patient with isolated frontal forelock with minimal anterior hair. (B) One year after a single session of 1500 grafts. The fronto-temporal angle has been created giving a natural-appearing hairline. Interestingly, the patient stopped dyeing his hair after the transplant. The presence of hair frequently creates a more youthful appearance to the face, independent of color.

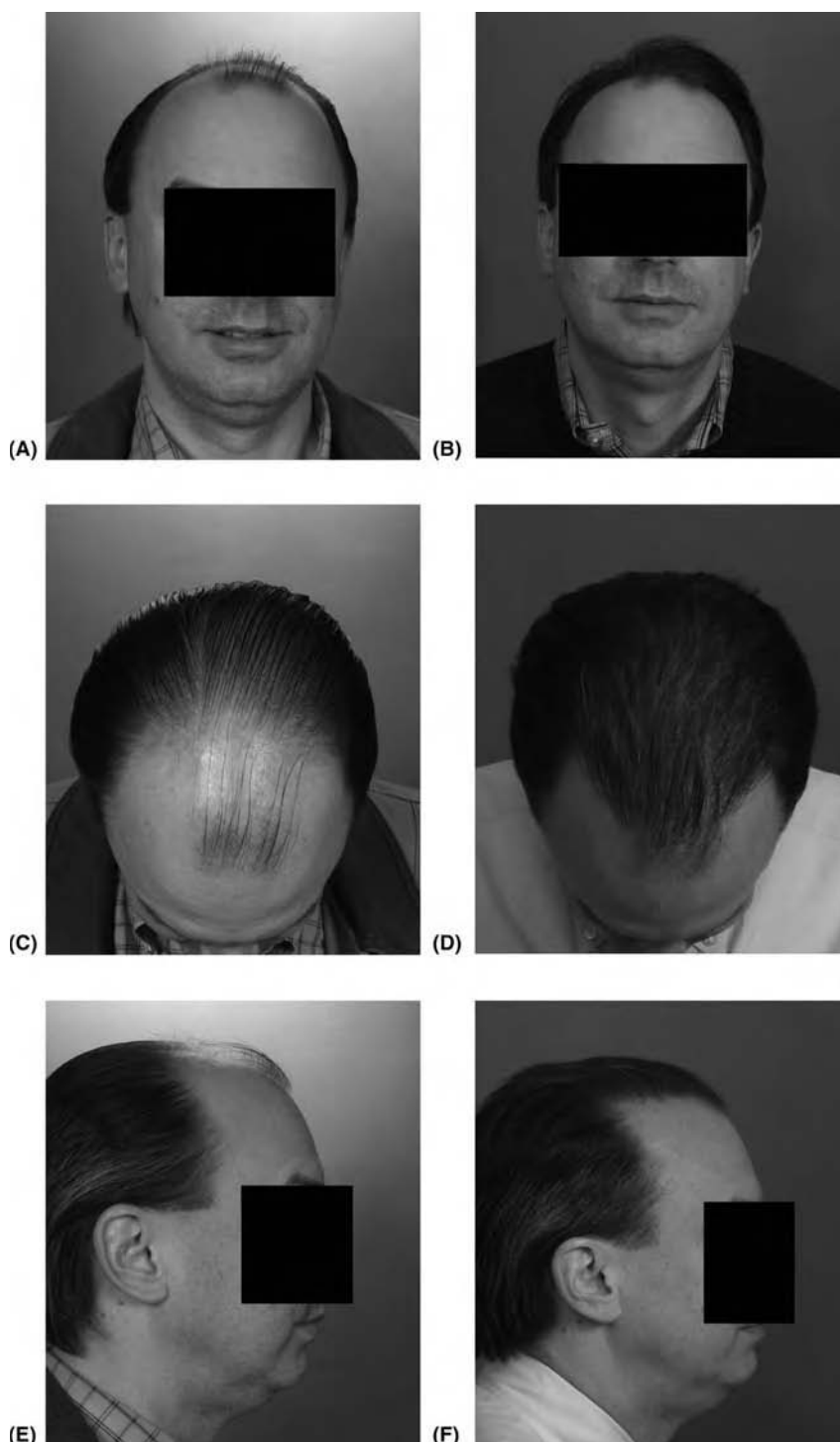


FIGURE 3 (A) A preoperative photo of a 44-year-old patient with extreme anterior hair loss with a small, isolated anterior frontal forelock. Photos of the patient revealed a high hairline with temporal recession even as a young man. (B) Appearance one year after single session of over 1700 micrografts. (C) Overhead view showing extent of hair loss. (D) Appearance one year after the single procedure. (E) Preoperative side view showing the angle of the temporal hairline. (F) Postoperative side view showing maintenance of a fronto-temporal angle. One simple rule is that in these patients, the new hairline should be parallel to the ground to look natural. Also, small hairs with irregular placement make up the hairline. Creating a low hairline in this patient would look unnatural, especially since he never had one originally. A common problem in the first decade of hair transplantation, besides using large grafts, was creating inappropriately low hairlines.



FIGURE 4 (A) A 41-year-old female with typical androgenic alopecia. The patient has good hair density on the side and back. The hair is sparse on the top, but the patient maintains her original frontal hairline. (B) One year after 1100 grafts to the frontal area.

Although hair loss in women is frequently of a diffuse nature and may be related to a metabolic disease, such as thyroid disease; there is a subgroup of women who have hair loss patterns similar to men (16). Androgenic alopecia in women has several distinct characteristics. The hair loss begins at the vertex and moves anteriorly. The family history includes many bald male and female family members. These women maintain good density on both the sides and back and usually continue to maintain an anterior frontal hairline. This last characteristic is different from male pattern androgenic alopecia in which the frontal hairline usually elevates and temporal recession increases. Women with androgenic alopecia are good candidates for transplantation (Fig. 4). The other group of women who are candidates for transplantation are those with hair loss after aesthetic surgery, usually, such as facelifts and forehead lifts (17). Traumatic alopecia is usually due to hair-follicle ischemia after aesthetic surgery. Temporal, preauricular, and postauricular areas are the most frequently involved (18) (Fig. 5).

The hair loss may be the result of direct damage to the bulbs from a superficial subcutaneous dissection or it may be due to excessive skin tension causing ischemia. Usually, if the hair loss is due to a relative ischemia, which has put the hair follicles into a telogen phase, the hair will recover after several months. However, in those patients where hair loss is permanent, hair transplantation is a useful adjunct.



FIGURE 5 (A) Typical areas of hair loss seen after a facelift involving temporal preauricular and postauricular areas. Previous attempts to cover areas of alopecia with tattooing were unsuccessful. (B) One year after transplantation to the temporal and postauricular neck area. Proper angulation of the grafts is critical in these areas. In the temporal area, the hair sweeps down and slightly posteriorly, while behind the ear, near the neck, it sweeps acutely downward.

ASSOCIATED PATTERNS AND TYPES OF BALDNESS

Androgenic alopecia is the most common type of hair loss and is due to the sensitivity of specific hair follicles to androgens. This type of hair loss, which is genetically predetermined, causes a reduction in growth rate, a reduction in hair-shaft diameter, and a lengthening of the anagen phase in the susceptible areas of the scalp. Five-alpha-reductase converts testosterone into dihydrotestosterone (DHT), and it is the DHT that acts on target cells, initiating this process (19). Most men initially experience this type of hair loss in the frontal and crown areas.

Adult hair consists of two types: vellus, which is short, soft-hair found diffusely over the body surface, and terminal hair, which is the coarse, long, pigmented hair on the scalp, eyebrows, and pubic area. As androgenic alopecia progresses, the terminal hairs slowly evolve into vellus in the affected areas. Hair density varies greatly between 200 and 400 hairs/cm² and this number dramatically declines as alopecia advances. The hair itself tends to grow in units called follicular units (20,21). Although these units vary in number, typically, they consist of one to three hairs growing in a cluster. The older procedures using large plug grafts with 20 to 40 hairs per graft created the classical doll hairs or corn row appearance because these grafts violated these normal follicular units of one to three hairs.

In order to document the pattern of androgenic alopecia, several classification systems have been devised. Each of the systems has limitations because patterns of hair loss vary so much from patient to patient. The system devised by Norwood is the one most universally used (22).

As mentioned, hair grows in follicular units and the follicles themselves go through cycles of growth and degeneration that play an important role relevant to hair loss and transplantation. Anagen is the growth phase, which lasts between two and five years and involves approximately 90% of the scalp hair at any one time. Catagen is the relatively short regression phase, lasting two to three weeks. Telogen is the resting phase, lasting three to six months, in which hair growth ceases. It is the telogen phase that has great clinical significance when discussing hair transplantation, as well as post-traumatic hair loss. When a follicle is transplanted, it goes into telogen, which is why the hair transplant patient sees no growth of the new hair during this phase (Fig. 6). Also, the patient who has had hair loss after a facelift or forehead lift will frequently have hair regrowth after three to six months. Thus, the majority of patients with this form of traumatic hair loss need reassurance, and only after six to nine months should surgical intervention be considered.

In 1959, Orentreich introduced the terms donor- or recipient-site dominance (23). This concept that the hair maintains the characteristics from where it comes, not where it goes, is critical for hair transplantation and allows for the transfer of hair from the posterior scalp, which is rarely lost over time, to the front of the scalp. Men rarely lose the hair in the extreme posterior scalp; thus donor-dominant grafts continue to grow long term. Orentreich's work utilized punch grafts for harvesting the donor site. Frequently, 3.5 to 5.0 mm punches were used to harvest donor tissue containing large number of hairs. This technique became the standard for over 30 years, unfortunately, creating many unnatural results (24). Even when smaller plugs with six to 10 hairs began to be used, the results were still poor. Therefore, it was not until the last decade, with the popularity over of small micrografts containing one to three hairs, that transplantation techniques began to create natural results. These small grafts, as mentioned earlier, are based on the natural clustering of hair follicles.

PATIENT EVALUATION

One simple fact which makes hair restoration difficult is the progressive, unpredictable nature of hair loss. Even a well-executed hair transplantation that looks good at 40 years of age, may not look good at 60 years of age because of the continuing nature of hair loss. Thus, a careful evaluation of the patient, taking into consideration: age, family history, hair pattern, hair type, and other factors is critical in planning and performing this procedure. Therefore, a hair pattern must be designed that not only looks good in the present, but will also look good in the future, based on the progression of hair loss.

Age is a critical factor in hair restoration. Many patients who had hair transplantation in their 20s will later regret the procedure because of continued hair loss (Fig. 7). The young

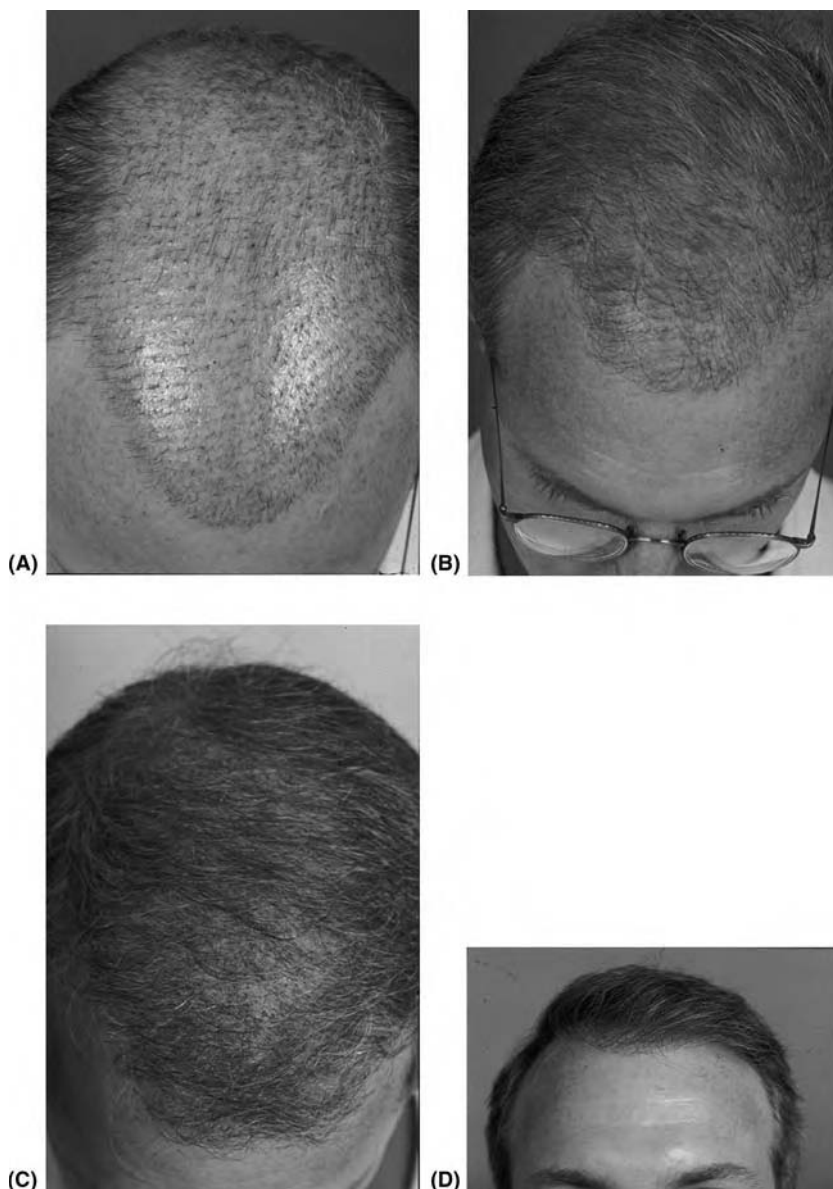


FIGURE 6 (A) Area transplanted with slightly over 1600 grafts, 12 days postoperatively. This case demonstrates the timeline seen with hair growth after transplantation. (B) Appearance at four months post-transplantation. The grafts are beginning to come out of the three-to four-month telogen phase induced by the surgery. (C) Six months postoperatively a significant increase in hair length and density. (D) At 18 months, grafted hair has excellent density.

patient who has early temporal and frontal recession and wants a rounded, juvenile hairline, will usually regret the procedure as he grows older. The grafts, which often are placed too low in these patients, became exposed and isolated as the hairline recedes posteriorly, creating a bizarre appearance (Fig. 8). These patients may have to choose between continued further grafting to fill in the developing gaps or having the original set of grafts removed (Fig. 9). Young patients who demand an inappropriately low hairline should be rejected; they frequently have unrealistic expectations. Also, patients with extensive hair loss and only a small, remaining posterior fringe need to be cautioned. Some of these patients with major hair loss can have satisfactory results as long as their expectations are realistic. Usually a frontal forelock



FIGURE 7 A 46-year-old patient had transplantation in his 20s. Although the grafts are fairly small, the problem is the progression of hair loss behind the grafts, which creates a strange appearance.



FIGURE 8 Patient had large plug grafts at an early age. Initially, the plug grafts were concealed by the patient's own local hair, but as androgenic alopecia progressed, the plugs became more obvious and isolated from the receding hairline.

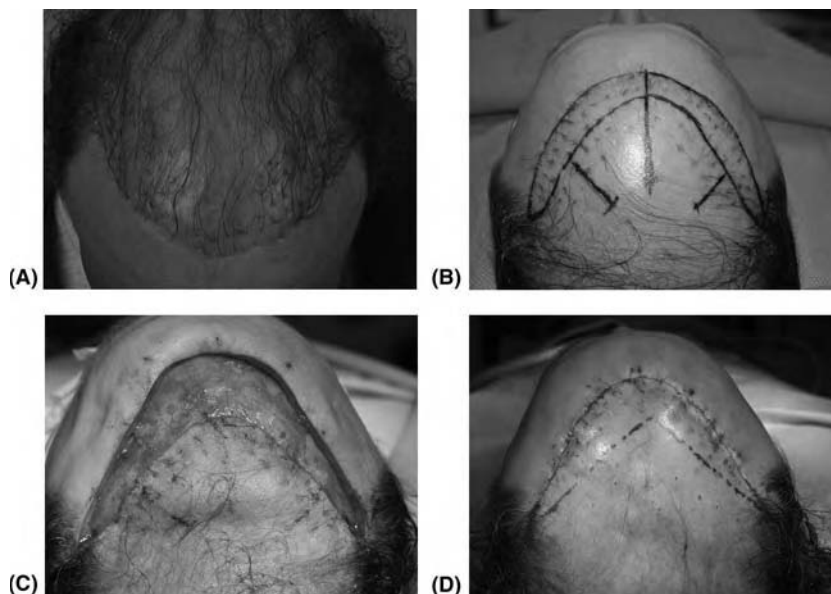


FIGURE 9 (A) Patient had plug grafts inserted at a young age and went completely bald behind them. The plugs were inserted in a perfectly straight line, creating an unnatural appearance. Another drawback to the plug grafts was the extent of visible scarring they created in the recipient site. (B) The plug grafts were limited to the anterior row, and the patient wanted no further grafting. The area to be excised is marked. (C) The majority of the plug grafts have been removed. The forehead has been freed to just above the eyebrows and will be advanced superiorly to close the defect. (D) The defect is closed using bony fixation to elevate the flap and skin closure with a subcuticular suture. Patient felt that the scar was far superior to the old plug grafts and declined further grafting.

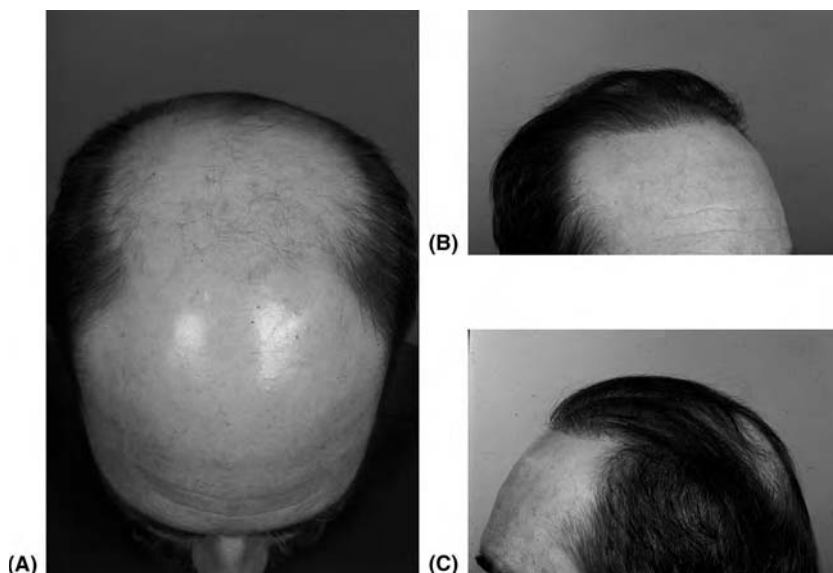


FIGURE 10 (A) Patient with extensive hair loss (Norwood classification VI). These patients have limited donor hair. Preoperative evaluation includes assessment of realistic expectations and adequacy of donor hair density. (B) A frontal hairline was created with 1900 grafts, and at 15 months patient has good density. (C) Side view demonstrates anterior placement of grafts, which extend posteriorly to the mid-ear level. The remaining coverage is accomplished by combining the hair posteriorly. The occipital area remains without hair. This procedure creates facial framing, but does not cover the entire area of alopecia.

can be created, which produces the phenomenon of facial framing. Rarely can these patients attain total coverage (Fig. 10). Also, the occipital area must be carefully evaluated. If a great deal of hair is densely transplanted into the occipital area and later hair loss progresses, a bizarre halo, or ring of baldness, appears around this permanent tuft of hair. The patient undergoing occipital transplantation must understand the likelihood of further grafting required in this area as baldness progresses. One method of reducing this problem is to lightly transplant the occipital area, placing the majority of grafts above the line where the original occipital hair swirl was present. Patients can then comb the transplanted hair posteriorly, covering up the bald site, with less risk of developing a bizarre tuft of hair surrounded by a bald halo (Fig. 11).

When initially evaluating a new patient for hair transplantation, a family history can be useful. Although it is frequently stated that males tend to inherit their hair pattern from the maternal side, in reality, the patterns are multifactorial and genetic hair loss can be associated with either side of the family. When the patient reports significant hair loss of brothers, grandfathers, and uncles, it is predictable that this patient may also have extensive hair loss over time. Therefore, any planned procedure must allow for extensive future hair loss. Also, since donor hair is a limited commodity, assessment of its density, or lack thereof, is critical in the evaluation. If a young patient already has sparse hair in the donor site, a conservative approach is necessary. The younger patient with very dense donor hair is a far better candidate. The young patient with potential extensive hair loss may be better off delaying surgery until hair loss has stabilized at a later date.

To demonstrate to the patient an appropriate hairline, one technique is to draw it during the consultation on the patient's scalp with them looking in the mirror (Fig. 12). Also, having patients bring in a photo of their appearance prior to hair loss may be very useful. Many of these patients always had high hairlines, with temporal recession even when they were young. If a well-designed, high hairline is not satisfactory to the patient, then it may be best not to perform the procedure.

Some patients with significant hair loss maintain an anterior isolated frontal forelock (Fig. 13). These patients are sometimes self-conscious because they develop a strange appearance.



FIGURE 11 (A) View several days after transplantation of the occipital area. The majority of grafts are placed high above the original area of the normal swirl. (B) Fourteen months postoperative. The patient has reasonable coverage of the occipital scalp. Because hair loss is progressive, overgrafting the occipital area can lead to a strange appearance. The grafts continue to survive while the surrounding hair recedes, leaving a central tuft with a surrounding ring of alopecia. Conservative grafting in this area reduces the chance of this problem occurring. In young patients, this area should be avoided until the hair loss stabilizes.



FIGURE 12 Hairline has been marked out during consultation so the patient can visualize the area to be transplanted. The markings show the irregularity created with a zigzag line formed around a straighter base line. The hairline is more than 10 cm above the glabella, with temporal recession.

The permanent, isolated, frontal tuft becomes isolated from the rest of the hair, and connecting this anterior tuft with the remaining hair normalizes the patient's appearance.

ANESTHESIA

The majority of patients have hair transplantations performed under local anesthesia. Many surgeons supplement with intravenous or oral sedatives. The scalp is relatively easy to

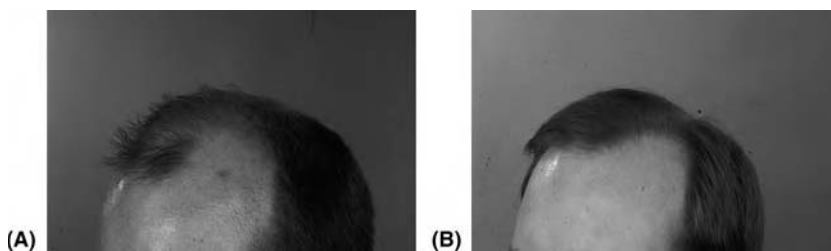


FIGURE 13 (A) A 32-year-old patient with isolated tufts of anterior hair (isolated frontal forelock). (B) One year after a single session of 1600 grafts that have connected the anterior isolated tufts of hair with the remaining hairline. An isolated forelock often creates a strange hairline, and connecting it to the stable posterior hairline significantly improves appearance.

anesthetize. The donor area can be treated with both occipital nerve blocks and a ring block around the donor ellipse. Tumescing the donor area with a dilute solution hydro dissects the tissue in the donor area, facilitating tissue elevation in the correct plain, deep to the follicles but above the nerves. A properly elevated donor specimen contains fat around the follicles. The tumescent fluid is a dilute saline-lidocaine-epinephrine solution. Scalp blood vessels, because of their fixation to surrounding connective tissue, do not contract as well as in other areas of the body. Thus, cauterization is frequently necessary, even when vasoconstructive agents have been used with the local anesthetics.

In the recipient area, supraorbital and supratrochlear blocks facilitate the ring block of the anterior scalp. Again, a tumescent solution is injected into the recipient scalp. Tumescing the recipient scalp has two benefits: first it aids in hemostasis and second, by elevating the soft tissue of the scalp, it facilitates the placement of the grafts.

SURGICAL TECHNIQUE

Although hair transplantation can be used in varied applications, the surgical technique is fairly consistent from patient to patient. Numerous complex devices to facilitate the procedure have been tried with little success. The actual instrumentation used today is simple and relies more on the facility of the surgeon and less on a fancy gizmo. Carlos Uebel is one of the pioneers who developed a simplified, reliable technique for the implantation of large numbers of grafts within a reasonable time period with simple instrumentation (25). In the past, transplantation of 100 to 200 grafts was considered to be a major procedure, while today, using current techniques, 1500 to 2000 grafts transplanted at one session are common.

The donor site is located approximately 6 to 7 cm above the hairline in the posterior scalp in primary cases. It is critical to properly angle the knife blade slightly upward to avoid transecting the hair follicles (Fig. 14). For many years, a multiblade knife, which created three to four strips simultaneously, was the preferred instrument for harvesting the donor site. The problem with this device is that it increases follicle transections along the multiple cuts. Today,



FIGURE 14 The hair has been trimmed in the donor area. The knife is angled slightly upward in order to cut parallel to the hair shaft and follicles. In primary cases, the donor site is usually 6 to 7 cm above the lower border of the hairline.



FIGURE 15 The elliptical strip has been removed, and care taken to protect the follicles during dissection.

most surgeons take out a single elliptical strip and then carefully cut it into cross sections, which are then cut into the individual grafts. Once the strip is removed from the scalp, the cross sectioning or bread loafing is done under magnification, again reducing the transection of follicles. The next step in which each bread-loaf slice is cut into individual grafts, is again done with magnification, insuring the quality of the grafts.

The strip that is harvested from the posterior scalp typically varies from 1.2 to 1.8 cm in width, while the length of the strip varies greatly on the number of grafts needed (Fig. 15). In a patient with average hair density in which 1200 to 1500 micrografts are needed, the strip can vary from 10 to 18 cm or more in length. Fortunately, the skin of the posterior neck and scalp in the donor area are fairly mobile and these excision sites close easily in primary cases (Fig. 16). Unfortunately, in the past, many patients had multiple procedures with different donor sites used at each session, creating a step ladder of multiple transverse scars in the posterior scalp. In these patients, when performing secondary procedures, closure can be difficult for two reasons. First, multiple, donor-site scars generate significant scarring, with loss of tissue elasticity. Second, if the parallel donor scars are close together, re-elevation of the tissue can lead to devascularization with tissue loss. In primary cases and follow-up procedures, most donor sites can be reharvested, incorporating the original donor scar. This method leaves the patient with a single scar, which looks better and heals better. Usually, in primary and even secondary cases, minimal flap elevation is required for a tension-free closure. However, in the badly scarred patient, especially, if previous plug grafts were harvested by a coring technique, which healed by secondary intention, closure may be difficult and extensive undermining may be necessary.

Some surgeons rapidly close the donor site with staples, but the preferred technique by this author consists of a deep layer closure with 3-0 Vicryl, followed by a running 3-0 nylon suture. This two-layered closure gives good tissue apposition and usually heals with an acceptable scar. The next phase of the procedure consists of creating hundreds of small grafts containing one to three hairs. The need for quality in graft preparation cannot be overstressed. Some cases of poor hair growth can be due to poor graft preparation. However, there is the occasional case where, even with excellent grafts, a significant number fail to grow for unknown



FIGURE 16 The donor site closes with minimal tension because of the laxity of tissue in this area. Closure is in two layers, with deep Vicryl and superficial running nylon. Suture can usually be removed in about 10 days.

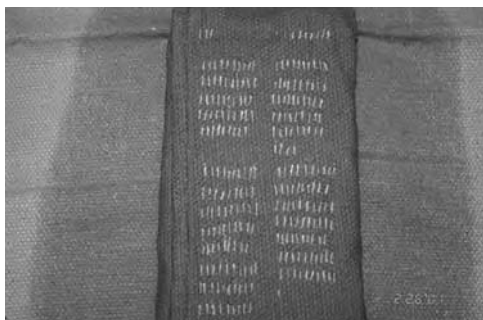


FIGURE 17 Two hundred and fifty micrografts sorted on a towel soaked with chilled saline ready for transplantation. The grafts have been sorted in rows of 10 according to size. The grafts have been created using magnification and contain primarily one to three hairs each.

reasons. Just as skin grafts can fail, so can grafted hair follicles. On the other hand, it is remarkable how, in the majority of patients, hair graft-take is extremely high. It is important to have an experienced team who can cut a large number of high-quality grafts (Fig. 17).

Once an adequate number of grafts is cut, the implantation process begins. In a session of 1200 to 1500 grafts, once a third of the grafts are ready, the process of implantation can begin. Using the Uebel technique, the surgeon places the grafts with a stick and place method. This method uses very simple instruments, consisting of a fine knife blade and small pickups (Fig. 18). The surgeon makes a small incision in the scalp, while the assistant, gently holding the micrografts with the pick-ups, guides the graft along the blade toward the opening made by the incision. The surgeon withdraws the blade slightly, applying pressure against the opening, pushing the opening to facilitate placement, and then uses the tip of the knife to finish inserting and positioning the graft. This process sounds complex and tedious, but in reality, once it is mastered, it takes five to six seconds to implant a graft, which translates into 500 to 600 grafts implanted per hour. This may sound like a lot, but some surgeons exceed this number as their facility increases. The key to this technique is having an assistant whose dexterity and timing matches the surgeon's. The grafts themselves are kept on cold saline towels in rows of 10, assorted by size. The assistant holds the towel in one hand and feeds the surgeon the grafts with the other. To date, this simple technique has made most attempts at automated instrumentation unnecessary.

During the implantation process, the grafts are placed as close as possible to each other. If the patient has a good scalp with no scarring and minimal dermal atrophy, the grafts can be placed a millimeter apart, if not closer. Also, once tissue thrombin has taken hold of the grafts, returning to a previously implanted area may allow for even closer implantation.

The grafts are properly angled in their recipient sites by holding the knife blade at the correct angle. Along the anterior hairline, the incisions are angled anteriorly, which allows the hair to exit the scalp at the proper angle. The smallest single-hair grafts make up the hairline margin in order to create a feathered zone and are placed with irregularity in a zig zag pattern (Fig. 19).

It is often hard for surgeons who have been trained to create symmetry and evenness to initially remember that a natural hairline is uneven and irregular. Once the procedure is



FIGURE 18 Grafts are inserted using the Uebel technique of stick and place. The surgeon makes a small slit while the assistant slides the grafts along the blade toward the opening. Once the graft enters the opening, the surgeon removes the blade slightly and positions the grafts.



FIGURE 19 Grafts have been inserted. The anterior hairline is irregular, with the smallest grafts of single hairs along the margin.

completed, a postoperative dressing is applied. Although some physicians apply nothing, most use some sort of dressing for 24 to 48 hours. The small grafts quickly become fixed in place and after the dressing is removed, careful washing of the area is acceptable. By postoperative day four or five, the grafts are well fixed and most patients can wash their hair normally. Usually, donor sutures can be removed after 8 to 10 days. Most patients have few postoperative problems, and since the final result takes at least six to eight months, frequent visits are unnecessary. Occasionally, the epithelium over the graft will close causing a cyst or ingrown hair. Washing the scalp frequently reduces this problem and using a needle to open the cyst usually is curative. If the grafts are placed with their epithelium slightly higher than the epithelium of the recipient, scalp cyst formation is greatly reduced.

CONCLUSION

Proper patient evaluation and selection of the correct surgical procedure are critical components in hair transplantation in both primary and secondary cases. In the last decade, the results



FIGURE 20 (A) A 38-year-old patient had large plug grafts in his early 20s. The grafts were placed too low and the hairline was poorly designed. The hairline is abnormally straight without a fronto-temporal recession. (B) The patient had excision of the entire row of anterior plug grafts with a forehead lift. (C) After two sessions of micrografting with almost 3000 grafts, the patient has had a dramatic improvement.

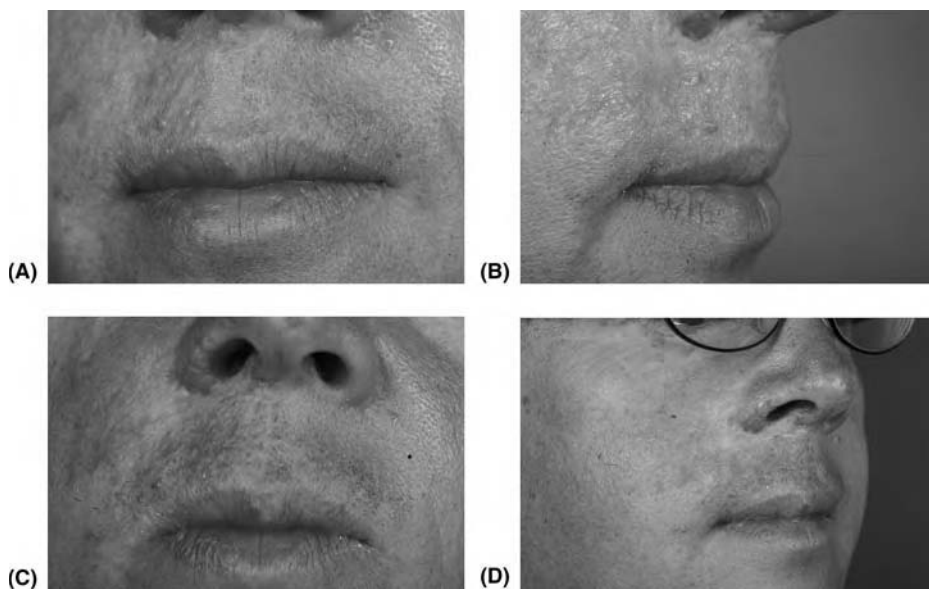


FIGURE 21 (A,B) Patient was born with a facial vascular malformation on the right side extending to the midline. As a child, he had a surgical resection with skin grafts. The right side of the face has no hair above the right upper lip. (C,D) Sixteen months after single hair grafts transplanted above the right upper lip. The patient shaves the area creating stubble matching the left normal side.

with hair transplantation have dramatically improved with the transit on from large to small grafts. Hairlines also are designed today with a more natural contour. Because of these developments, cases which in the past were not amenable to improvement, now can be corrected with dramatic results (Fig. 20). Also, with the advent of small grafts, cases not previously appropriate for hair transplantation can now be managed (Fig. 21).

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8 Forehead/Brow/Soft-Tissue Surgery for Migraines

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INTRODUCTION

Migraine headache (MH) is a chronic, often incapacitating condition that afflicts approximately 28 million Americans (12% of the population), disproportionately affecting more females (18%) than males (6%) (1,2). One out of every four households has someone who is plagued with migraines, interfering not only with his or her job performance, but also interpersonal relationships, and social outings (1). This translates to a collective loss of 112 million workdays and \$14 billion in productivity, creating a significant public burden (3). Nevertheless, this condition remains largely under diagnosed and undertreated.

It is estimated that the median frequency of attacks is 1.5 per month, and the median duration of an attack is 24 hours (4). At least 10% of migraine sufferers have weekly attacks, and 20% have attacks lasting 48 to 72 hours (5). There are even some patients who experience daily MH. Most standard prophylactic and abortive treatments can be effective, although even the most efficacious medications may only reduce the severity and frequency, but not entirely eliminate MHs (6,7). To be most effective, the medications must be used in the early stages of the migraine domino process, before the onset of pain or when the pain is mild. Once the pain is fully established, however, the treatment becomes less effective and many patients have to resort to secluding themselves in a dark, quiet environment to avoid any external stimuli that may compound their tremendous agony until the migraine subsides. It is intriguing, however, that given the disabling effects of MH, an overwhelming majority of patients debilitated by this chronic condition are realistic and are willing to settle for some improvement and not necessarily aim for total elimination of migraines.

The serendipitous observation of patients whose headaches had disappeared after forehead rejuvenation prompted the senior author (BG) to begin a series of studies that mark the beginning of what is believed to be a new era for management of MH and the beginning of a better understanding of the pathophysiology of this condition (8–10). Over the last five years, a number of surgical techniques have been developed that have gradually led to a cautiously optimistic prospect for elimination of MH for most patients. This chapter discusses the pathophysiology of MH, the means by which the different trigger sites can be identified, and the surgical treatment that has been devised for each trigger site.

CLINICAL PRESENTATION OF MIGRAINE HEADACHES/DIAGNOSIS

MHs are often characterized as intense throbbing pain episodes that may be severe. The pain is usually unilateral, although it can occur bilaterally. Furthermore, the moderate to severe pain typically disrupts a person's daily activities and is aggravated by movement and routine activities. MHs are commonly accompanied by responses resultant from concomitant activation of the sympathetic nervous system including nausea, vomiting, diarrhea, facial pallor, cold hands and feet, and sensitivity to light, sound, or movement (1,7,11). A typical attack lasts between 4 to 72 hours, during which time migraineurs prefer to remain in a quiet, dark environment due to their increased sensitivity. The symptoms described above distinguish MH from other types of headaches, although not all of these features are present in every attack, nor are these symptoms present in every person suffering from MH. For a diagnosis of MH, a person must experience a combination of the above features (Table 1) (12).

MHs generally begin in childhood to early adulthood, peaking in midadolescence. Although attacks of MH can initially occur in individuals 50 years or older, other types of

TABLE 1 Diagnostic Criteria for Migraine Without Aura as Specified by the International Headache Society

Headache attacks lasting 4 to 72 hours
Headache has at least two of the following characteristics:
Unilateral pain
Pulsating/throbbing in nature
Pain of moderate or severe intensity that disrupts daily activities
Aggravation by routine physical activity and movement
During the headache, at least one of the following symptoms is present:
Nausea and/or vomiting
Photophobia or phonophobia

Source: From Ref. 12.

headache in this age group are more likely. Moreover, a family history is usually present, suggesting a genetic predisposition for this condition (13–15).

An estimated 40% to 60% of MHs are preceded by premonitory signs lasting hours to days (11,16). The common symptoms include irritability, fatigue, depression or euphoria, yawning, food cravings for sweet or salty food, and sensitivity to bright lights.

An estimated 20% of MHs are associated with an aura that can last from several minutes to an hour. The most common auras are changes in vision (seeing flashing, brightly colored lights, or development of a blind spot). Less common auras include numbness of the fingers, hands, or lips, auditory hallucinations, and abnormal tastes or smells preceding MH (11,16).

After a MH has resolved, the migraine sufferer may experience lingering symptoms resembling flu-like symptoms that can last for up to 24 hours. These symptoms include fatigue, poor concentration, nausea, tender muscles, and low-grade headache along with sensitivity to light and sound (11,16).

SURGICAL BACKGROUND AND SIGNIFICANCE

Surgical attempts to treat MH date back to 1931. Walter Dandy, believing that “the actual pain of MHs, so perfectly restricted to one side of the head (unless both sides are involved), must indicate an affliction of nerves which carry sensation,” removed the inferior cervical and first thoracic sympathetic ganglions in two patients (17). Interestingly, he was able to eliminate MH in both of these patients. However, this pioneer work lacked scientific significance due to a small patient sample size, absence of a control group, and an extremely short follow-up period.

Resection of the greater superficial petrosal nerve in the treatment of various types of unilateral headaches was suggested by Gardner et al. in 1946 (18). Twenty-six patients underwent surgery, nine of whom were felt to have unilateral MH, including seven women and two men. All patients with MH experienced either complete elimination or significant improvement. Two patients had initial improvement, but the MH recurred after seven to eight months. The authors concluded that the surgery was more successful in patients with MH than for other indications. The patients, however, reported a reduction in tear production and dryness of the nose. Some patients even developed corneal ulcerations. The fact that a diverse group of patients underwent the same procedure without sufficient follow-up and without controls diminishes the scientific merits of this study. Furthermore, dryness of the eyes (possibly leading to blindness) and nose are major adverse consequences, thus rendering this type of surgical approach unjustifiable.

Total resection of the trigeminal nerve within the cranial base (trigeminal neurectomy) has also been advocated. Anesthesia of the ipsilateral hemiface, dryness of the cornea, corneal ulceration, and loss of vision may ensue such a complex procedure. This operation is still being performed in some centers, but only on patients with severe cluster-type MH. Surgery of this magnitude is too radical and the associated morbidities are grave.

Murillo, in 1968, introduced resection of the temporal neurovascular bundle for control of MH (19). This surgery included removal of the superficial temporal artery and auriculo-temporal nerve. The procedure was effective in elimination of MH in 30 of 34 patients. This report, however, did not include the length of follow-up, nor was there a control group for this clinical

trial. It is the author's belief that, based on his own anatomical investigations, there is an arcade between the zygomaticotemporal branch and the greater occipital nerve through small horizontal branches. By interrupting this arcade, some of the temporal headaches may temporarily cease. This treatment would not offer any benefits to those who suffer from frontal, occipital, or rhinogenic MH. Additionally, the resultant numbness and the temporary nature of the benefits would not merit the routine use of this surgery as the only surgical procedure. Transection of these branches may add to the success of procedures described later in this chapter.

A greater occipital neurectomy was suggested for patients with occipital MHs and neuritis by Murphy in 1969 (20). This operation was performed on 30 patients, 15 males and 15 females. Eighteen patients had excellent results, seven had good results, three had fair, and two had poor results. Many of these patients, however, had less than one-year follow-up. Murphy's report did not indicate the incidence of anesthesia or paresthesia in the occipital region, nor did it outline any other adverse effects resulting from the surgery. Transection of this nerve, in all likelihood, would result in unacceptable anesthesia at a site in which sensation is important in order to prevent potential pressure ulcers, since most individuals sleep in the supine position. Nevertheless, the positive results of the surgery indicated a contribution from a peripheral mechanism in the pathogenesis of MH.

In 1992, Maxwell reported trigeminal ganglio-rhizolysis for the treatment of MHs in eight male patients through percutaneous radiofrequency (21). The patients had moderate to significant relief of MHs with no reported complications. This study also lacked a placebo-control, sufficient follow-up, and sufficient patient sample size, as has a study that examined closure of patent foramen ovale (22). Even techniques such as cryosurgery and injection of alcohol have been attempted for treatment of MHs. The unscientific manner in which these studies were conducted precludes any meaningful conclusions. The indications for these surgeries, however, are limited and very specific.

The senior author's (BG) investigation of the surgical treatment of MH began following reports from patients that their MH had disappeared subsequent to a forehead procedure that involved the removal of the corrugator supercilii muscle group. This prompted us to conduct a retrospective study to determine whether there was an association between the removal of the corrugator supercilii muscle and the elimination or significant improvement of MH. Questionnaires were sent to 314 consecutive patients who had undergone corrugator supercilii muscle resection during endoscopic, transpalpebral, or open forehead rejuvenation procedures, of which 265 responded. The patients were queried as to whether they had a history of MH prior to surgery and, if so, whether the headaches improved significantly or disappeared after surgery. If the answer was affirmative, they were further questioned about how long after the surgery they noted the change in MH frequency or intensity and how long this change lasted. After an initial evaluation of the completed questionnaires, a telephone interview was conducted to obtain further information necessary to ensure that the patients had a correct diagnosis of MH based on the International Headache Society criteria. Of the 265 patients who were contacted, 16 were excluded because of the provision of insufficient information to meet the International Headache Society criteria, the presence of organic problems, or other exclusions mandated by the study design. Thirty-nine (15.7%) of the remaining 249 patients had MH that fulfilled the diagnostic criteria. Thirty-one of the 39 patients (79.5%) with preoperative MH noted elimination or improvement (at least 50% reduction in frequency or intensity) in MH immediately after surgery ($p < 0.0001$; McNemar), and the benefits lasted over a mean follow-up period of 47 months. When the respondents with a positive history of MH were further divided, 16 patients noticed significant improvement ($p < 0.0001$; McNemar) over a mean follow-up period of 47 months, and 15 experienced total elimination of their MH ($p < 0.0001$; McNemar) over a mean follow-up period of 46.5 months. When stratified by MH type, 29 patients (74%) had MH without aura. Of these patients, MH disappeared in 11, improved in 13, and did not change in five ($p < 0.0001$). Ten patients experienced MH with aura. These headaches disappeared or improved in seven of them, and did not change in three ($p < 0.0001$). This study demonstrated for the first time that there is indeed a strong correlation between the removal of the corrugator supercilii muscles and the elimination, or significant improvement, of MH (8).

Being a retrospective study, these findings, although interesting, were of insufficient scientific merit. It was puzzling to the research team how a condition, the etiology of which is considered a central phenomenon, can be improved by manipulation of peripheral mechanisms. The potential role of peripheral factors became more tenable when the beneficial effects of botulinum toxin A (Botox®) on MH were reported (23–29).

A pilot study was designed by the senior author to investigate the role of removal of the corrugator supercilii muscles and transection of the zygomaticotemporal branch of the trigeminal nerve (ZTBTN) with repositioning of the temple soft tissue in the treatment of MH. The research team's neurologist evaluated patients with moderate to severe MH to confirm the diagnosis, utilizing the criteria set forth by the International Headache Society. Subsequently, the patients completed a comprehensive MH questionnaire and the team's plastic surgeon injected 25 units of Botox into each corrugator supercilii muscle. The patients were asked to maintain an accurate diary of their MH and complete a monthly questionnaire documenting pertinent information related to their headaches. Patients who experienced complete elimination of their MH after injection of Botox then underwent resection of the corrugator supercilii muscles. Those who experienced only significant improvement underwent transection of the ZTBTN with repositioning of the temple soft tissues, in addition to removal of the corrugator supercilii muscles. Patients kept a detailed postoperative record of their headaches.

Of the 29 patients included in the study, 24 (82.8%) reported a positive response to the injection of Botox ($p < 0.001$). Of the 24 patients who had a favorable response to the injection of Botox, 22 underwent surgery and 21 (95.5%) observed a postoperative improvement ($p < 0.001$). Ten patients (45.5%) reported elimination of MH ($p < 0.01$) and 11 patients (50.0%) noted a significant improvement ($p < 0.004$). Only one patient (4.6%) did not notice any change (NS). For the entire surgery group, the average intensity of the MH reduced from 8.9 to 4.1 on an analog scale of 1 to 10, while the frequency of MH significantly decreased from an average of 5.2 per month to an average of 0.8 per month. The follow-up ranged from 222 to 494 days, the average being 347 days. This pilot study confirmed the value of surgical treatment of MH. The shortcomings of this study were the lack of a control group, small sample size, and a short follow-up period. Significant information, however, was garnered from this study to facilitate the subsequent research described below. One fascinating discovery was that some MH might be triggered from the septonasal and occipital regions. Additionally, and perhaps equally as important, was the discovery that Botox can be used as a reliable prognosticator for the success of surgery at a trigger site. Furthermore, information obtained from patients pertaining to their individual "trigger sites" and a preponderance of symptoms in a specific site can be used to guide selective treatment.

Some patients who were successfully treated in the glabellar or temporal regions later reported headaches originating in the occipital or paranasal areas, indicating the presence of other trigger sites. Concurrently, some patients who underwent septoplasty and turbinectomy also stated that their MH had disappeared. In an attempt to understand the relationship between MH and the sinuses, septum and turbinates, a search of the literature regarding perinasal surgery was illustrative. Multiple publications reported the effectiveness of turbinectomy and septoplasty on elimination of or reduction in the frequency of MH (30–33).

The available literature on anatomical studies germane to the occipital trigger was somewhat vague. To elucidate the anatomy of this site, our research group dissected 20 fresh cadavers yielding 40 sites. It was intriguing to find that in all 40 sites, the greater occipital nerve pierced the semispinalis capitis muscle to reach the skin level (34). Findings from this study guided the senior author in determining the appropriate location for injection of Botox in the area and designing a surgical procedure to be used for the treatment of patients with an occipital trigger site.

Armed with new information and his surgical experience in this area with evidence for successful outcomes, the senior author designed a comprehensive study that included a control group. The diagnosis of MH was confirmed for all patients by the research team neurologists, and the internal nose was examined by the plastic surgeon. All patients completed health-related, SF-36, migraine disability assessment (MIDAS), and migraine specific quality of life (MSQ) questionnaires before treatment and at one year after surgery. On a random basis, 100 patients underwent injection of Botox to detect the trigger sites using an algorithm developed by the senior author (see next). Another 25 patients received injection of 0.5 cc of placebo and

served as a control group. If injection of Botox identified one or several trigger sites, evidenced by complete elimination or significant improvement (50% reduction in intensity or frequency) of MH, the patient was considered a candidate for surgery. If the injection of Botox failed to eliminate MH, and there was sufficient evidence of rhinogenic MH with a deviated septum and enlarged turbinates, septoplasty and turbinectomy were carried out. Surgery included any one of the following as a single procedure or in combination: removal of the corrugator supercilii muscle group (including *depressor supercilii* and *procerus* muscles), detachment of the ZTBTN, partial removal of the semispinalis capitis muscle to release the greater occipital nerve, septoplasty, and turbinectomy. All patients kept an accurate record of their headaches postoperatively.

The data from the first year follow-up after migraine surgery have been recently reported (10) and are summarized here. Of the 100 patients in the surgery group, 98 patients underwent injection of Botox to identify their trigger sites and 91 underwent surgery. Of the 91 patients who underwent surgery, 89 completed follow-up requirements and constituted the final "treatment" group. Only one trigger site was detected on 11 patients, 21 patients had two trigger sites, 39 patients had three trigger sites, and 20 patients had four trigger sites. All of the patients with multiple trigger sites identified one site as being the predominant MH site, and the others were considered secondary sites. Of the 89 patients in the treatment group who completed the study, 82 demonstrated at least 50% reduction in MH frequency, duration, or intensity compared to the baseline data; 31 (35%) reported elimination, and 51 (57%) experienced improvement over a mean follow-up period of 396 days. In comparison, three out of 19 control patients (15.8%) who completed one-year follow-up questionnaires recorded reductions in MHs ($p < 0.001$) and no patients observed elimination. All variables for the treatment group improved significantly when compared to their baseline and those of the control group, which included MSQ, MIDAS, and SF-36 health survey.

When the response to surgery was analyzed based on trigger sites, of the 80 patients with a frontal trigger site, 79 (99%) responded favorably to surgery, with 51 (64%) patients reporting elimination and 28 (35%) patients reporting significant improvement of their MH. For the 71 patients with a temporal trigger site, 70 (99%) responded favorably to surgery, 45 (63%) reported elimination, and 25 (35%) reported improvement. Surgery at the occipital trigger site produced a positive response rate in 34 patients, with 21 (62%) patients reporting elimination and 13 (38%) patients reporting improvement. Finally, septoplasty and turbinectomy were performed on 62 patients, yielding a favorable response in 55 (89%) of them [24 (34%) had elimination and 34 (55%) had improvement].

The mean annualized cost of migraine care for the treatment group was reduced significantly (\$925) compared to the baseline expense (\$7,612) and the control group (\$5,530); $p < 0.001$. The mean monthly number of days lost from work was reduced significantly (1.2 days) compared to the baseline (4.41 days) and the control group (4.4 days); $p = 0.003$.

The common adverse effects related to injection of BTX-A included discomfort in the injection site in 27 patients after 227 injections (12%), temple hollowing in 19 of 82 patients (23%), temporary neck weakness in 15 of 55 patients (27%), and eyelid ptosis in nine (10%). The common complications of surgical treatment were temporary dryness of the nose in 12 (19.4%), rhinorrhea in 11 (17.7%), intense scalp itching in seven (8.8%) patients who underwent forehead surgery, and minor hair loss in five (6.3%).

In a recent study in Vienna, Austria (35), the authors followed our initial report (8) and removed the corrugator supercilii muscle through a transpalpebral incision. The lead author of this report, a plastic surgeon who suffered from MH, persuaded another colleague to operate on him following the initial methods developed by us. Having enjoyed a successful outcome, he commenced his own study. From the entire group of 60 patients, 17 (28.3%) reported total elimination of MH, 24 (40%) an essential improvement, and 19 (31.6%) minimal or no change in their MH after a minimum follow-up period of six months. The methodology of this study was suboptimal due to the lack of a control group and not utilizing Botox for patient selection, which would have increased the success rate and allowed the focus on a single trigger site.

Taken together, all of the above-mentioned studies demonstrate that whenever the peripheral-to-central trigeminal pathway is interrupted, relief of migraine pain can be expected in most patients. However, many of those studies lacked a placebo-control group, a sufficient

number of patients, adequate follow-up, and assurance of patient safety. In contrast, the studies designed by our research group specifically address these deficiencies by inclusion of a sufficient number of patients, adequate follow-up time, placebo-controlled surgery, and design of surgical techniques that harbor minimal risks and provide utmost patient safety (10).

ETIOLOGY AND PATHOPHYSIOLOGY

The mechanisms underlying MH pathophysiology are poorly understood. Based on recent discoveries, a number of hypotheses have emerged regarding the neural events mediating the initiation of MH: (i) Cortical neuronal hyperexcitability underlying the brain's susceptibility to migraines (36,37). (ii) Cortical spreading depression (CSD) as the basis of aura that as many as 20% of migraine sufferers experience prior to the onset of headache (38). Similarly, there are data suggesting that cortical events similar to those underlying aura are also involved in migraines without aura (36). (iii) Peripheral and central activation and sensitization of the trigeminal system culminating in MH. (iv) Abnormal modulation of brain nociceptive systems due to the dysfunction of primarily the periaqueductal gray matter and alteration of its facilitatory or inhibitory pain processing functions (36).

Of these four concepts, which has the most relevance to our findings and which is supported by sufficient scientific evidence is peripheral activation of the trigeminal nerve and subsequent peripheral and central sensitization. MH is postulated to be caused by dilatation of large vessels innervated by the trigeminal nerve and activation of perivascular sensory fibers supplying the dura mater following an episode of CSD and meningeal inflammation (39–46). As mentioned above, aura appears to arise from CSD. Data from animal studies indicate that CSD may lead to MH via activation of the trigeminal nucleus caudalis and the upper levels of the cervical spinal cord, the central nervous system (CNS) regions that receive sensory input from trigeminovascular fibers and are involved in the processing of nociceptive information (47–50). Vasodilatation is the consequence of meningeal nociceptor-induced release of calcitonin gene-related peptide (CGRP), substance P, and neurokinin A found in the cell bodies of trigeminal neurons (51–55). The specific factors that prompt the initial release of these peptides remain unclear. We propose that it may be the mechanical stimulation of the potentially hyperexcited peripheral sensory nerves and ensuing bombardment of central neurons with pain impulses that instigates this process. In three out of four trigger sites studied by the senior author, the sensory nerves traverse the muscles providing a source of mechanical stimulation (9,34,56,57). As to the fourth site, contact between the turbinates and the deviated septum may cause MHs in some patients (30–33). Indeed, studies have shown that peripheral inflammation leads to increased excitability of central neurons (central sensitization) via the release of neuropeptides, resulting in amplification of sensory inputs including exaggerated responses to stimuli that are normally innocuous (58,59).

Strassman et al. showed that meningeal primary afferent neurons in the trigeminal ganglion of rats became mechanically hypersensitive (peripheral sensitization) after exposing the dura to inflammatory agents (60). This hypersensitivity of peripheral neurons has been proposed to mediate the throbbing nature of the pain associated with migraines as well as its worsening with physical activities such as coughing and bending over that increased intracranial pressure. Furthermore, brainstem trigeminal neurons receiving convergent sensory input from the dura and periorbital skin were shown to become sensitized after application of inflammatory agents to the dura (61). When central sensitization develops, neurons respond to innocuous and nociceptive stimulation of the dura as well as the periorbital skin in a similar manner (62).

In humans, periorbital skin hypersensitivity is manifested as cutaneous allodynia, resulting in misinterpretation of non-noxious stimuli as painful. A recent report indicated that most patients with MH (79%) exhibited cutaneous allodynia inside and outside their pain-referred areas when examined during a fully developed migraine attack (63). In a complementary study, the spatial and temporal aspects of the development of cutaneous allodynia were examined by measuring pain thresholds in the head and forearms at several time points during a migraine attack in a 42-year-old male (64). The authors found a gradual increase in the severity of allodynia over time as well as a gradual enlargement of the spatial areas exhibiting allodynia.

The results of the above studies suggest the following sequence of events along the trigeminovascular pain pathway (65): (i) sensitization of peripheral nociceptors mediates the symptoms of intracranial hypersensitivity. (ii) The barrage of impulses that come from the peripheral nociceptors results in sensitization of second-order central trigeminal neurons and this central sensitization is responsible for the development of cutaneous allodynia on the ipsilateral side of the head. (iii) The barrage of impulses originating from the sensitized second-order neurons activates and eventually sensitizes third-order neurons leading to the development of cutaneous allodynia in other parts of the body.

For maximal effectiveness, this interpretation mandates early use of anti-migraine drugs (triptans) that target peripheral nociceptors prior to the development of central sensitization. Recent studies have confirmed this notion by demonstrating in rats that triptan treatment effectively blocked the development of central sensitization only when administered simultaneously with meningeal stimulation (66). Similarly, in patients susceptible to allodynia during migraines, triptan therapy was more likely to provide pain relief if administered before the establishment of cutaneous allodynia (67). Triptans appear to exert their actions by blocking synaptic transmission between the axons of peripheral trigeminovascular neurons and their central neuron targets within the dorsal horn (68). This would function to prevent central sensitization by inhibiting the transmission of pain impulses coming from the periphery.

In a chronic constrictive injury model in rodents, temporary ligatures tied around the sciatic nerve resulted in local and remote allodynia and hyperalgesia (69). This temporary injury to the nerve resulted in permanent central changes in the dorsal horn, including an increase in the receptive field size and a lowered pain threshold. This observed that lower pain threshold is similar to the lowered pain threshold noted above and is one of the two chief mechanisms of migraine head pain. A lowered pain threshold results in a behavioral response of hyperalgesia and allodynia.

The reason why surgery is singularly effective as a treatment for MHs is not clear. We postulate that impingement upon the branches of the trigeminal nerve that pierce the fronto-temporal and occipital muscles and their resultant stimulation/activation causes changes within the CNS similar to those noted in the animal model with ligation of the sciatic nerve. In fact, studies have shown that stimulation of muscle afferents increases the excitability of central neurons (70–72) and muscle afferents appear to be more effective at inducing changes in central neuron responsivity compared to cutaneous afferents (71,72). Central sensitization increases excitability within the CNS, making the migraineur more susceptible to clinical “triggers” by a variety of agents such as tyramine, bright sunshine, or touching the scalp. Weakening and ultimately surgically removing the muscles that entrap and compress the trigeminal branches may abort the cascade of neurogenic inflammation and sensitization that leads to CNS excitation and thus migraine symptoms.

PATIENT SELECTION

There are a number of conditions that can easily be mistaken for MH. It is, therefore, crucial to have a confirmed diagnosis of MH by a neurologist prior to selecting any patients to undergo surgery.

To qualify as a surgical candidate, patients must be 18 years or older and experience at least two or more MHs a month that are severe enough not to respond to over-the-counter medications. Also, patients who sustain major side effects from medical treatments would be considered suitable candidates for surgical treatment.

CONSTELLATION OF SYMPTOMS TO AID IN IDENTIFICATION OF TRIGGER SITES

Patients should undergo extensive evaluation to identify the trigger sites. Trigger sites are identified in the following way. Patients are asked about the most common focal site of their headaches and these trigger sites are palpated for a patient response. Examination of the internal nose is undertaken to observe the septum and the inferior turbinates. There are constellations of symptoms that may aid in the clinical identification of trigger sites.

Frontal MH usually begin at the end of a stressful day, and the patients point to the pain site above the eyebrows, often along the course of the supratrochlear and supraorbital nerves.

On palpation, there is tenderness in this area and at the onset of the MH, light pressure in the area may prove soothing. However, firm and continuous pressure in the area may actually exacerbate MH.

Patients with temporal MH commonly wake up in the morning with pain in the temple area often starting from the emergence point of the ZTBTN from the temporalis muscle. The ZTBTN is a branch of the maxillary division of the trigeminal nerve that provides sensory innervation to the temporal area approximately 1.7 cm lateral and 0.6 cm cephalad to the lateral orbital commissure (57). On palpation, there is a depressed area in the temple that corresponds to the point of emergence of this nerve from the fascia. The pain extends cephalically and often spreads to the postauricular region and down into the neck area. Occasionally, the pain extends medially into the supraorbital area. Many of these patients grind their teeth at night, which may contribute to the onset of their headaches.

MH pain arising from the occipital region usually starts at the point of emergence of the greater occipital nerve from the semispinalis capitis muscle. The greater occipital nerve, which is the continuation of the medial branch of the C2 dorsal root, emerges from the underlying semispinalis muscle approximately 3 cm inferior to the occipital protuberance and 1.5 cm lateral to the midline as reported in a recent study by our group (34). The pain extends cephalically and sometimes even into the forehead area. A possible physiologic mechanism for this referred pain is spatial convergence of afferent input from the front of the head innervated by the ophthalmic division of the trigeminal nerve and the back of the head innervated by the greater occipital nerve (GON) onto the same central neurons (50,73,74). Occasionally, the pain extends caudally rather than cephalically. These patients sometimes wake up in the morning with headaches due to a specific head position while asleep. However, commonly, MHs originating from this site are stress-related and are more likely to occur late in the day or in the evening.

Patients who have nasal septum or sinus-related MH commonly describe the pain as originating from behind the eyes and radiating to the temple or occipital area, depending on which branches of the trigeminal nerve are involved. This is mainly the territory of the nasociliary branch of the trigeminal nerve and, for that reason, the pain is felt behind the eye in the supraorbital region and temporal region in the advanced stages of MH. These patients commonly experience MH when there is a change in barometric pressure and may wake up with MH. On examination, the most common intranasal pathologic finding is reversed C anteroposterior deviation of the septum (with the C facing the patient's right side) as well as enlargement of the right middle and superior turbinates. Commonly the inferior turbinate is enlarged as well. Those who suffer from intranasal or sinus-related MH should first be evaluated with an endoscopic nose examination and a computed tomography (CT) scan of the nasal cavity and sinuses. The CT scan findings may confirm the above findings as well as the presence of concha bullosa and Haller's cell. These findings may be present independent of septal deviation and could trigger migraine or sinus headaches (75,76). Rarely, patients with occipital headaches may describe referred pain behind the eyes and those with septum or sinus-related headaches may complain of pain in the occipital region.

THE ALGORITHM FOR IDENTIFICATION OF THE TRIGGER SITES

We have developed an algorithm to detect possible trigger sites in a sequential manner (Fig. 1). Patients with a confirmed diagnosis of MH receive an injection of Botox into three of the frontal (Fig. 2), temporal (Fig. 3), and occipital (Fig. 4) trigger sites in a logical, stepwise manner. The most common trigger site as suggested by the patient's symptoms is injected first. Generally, 25 units is injected into the bilateral glabellar muscle group and 20 units in the temporalis and semispinalis capitis muscles. If the injection of Botox in one or several trigger points results in complete elimination or significant improvement of the MHs (>50% reduction in intensity and/or frequency) during a period of at least six consecutive weeks, the patient is considered as a candidate for surgery. If the injection of Botox fails to eliminate migraines, and there is sufficient evidence of rhinogenic MH with a deviated septum and enlarged turbinates, septoplasty, and turbinectomy is carried out. A total of four trigger points may be identified in a variety of combinations based on the patient's response to Botox. These include the frontal trigger site (the glabellar muscles pinching the supraorbital and supratrochlear nerves) which occurs in

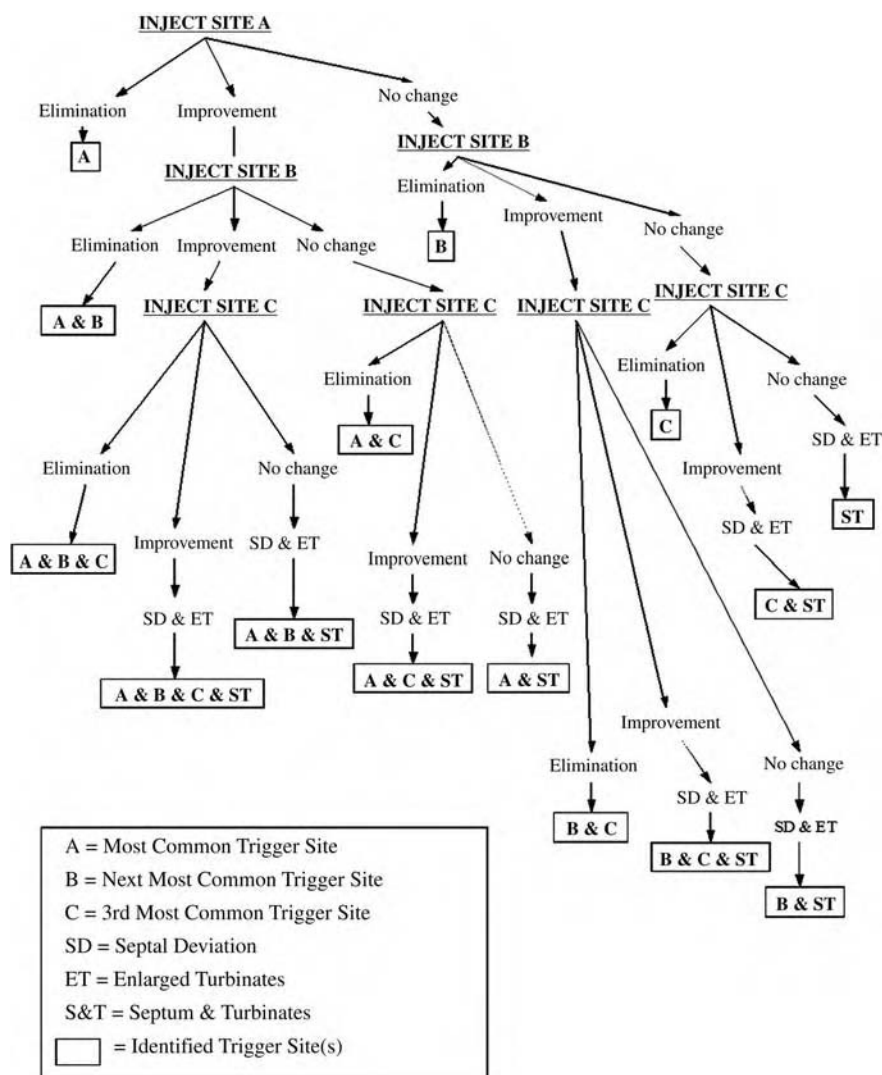


FIGURE 1 Algorithm for identification of the trigger sites based on response to injection of botulinum toxin A. *Source:* From Ref. 10.



FIGURE 2 Injection of botulinum toxin A in the glabellar muscle group.

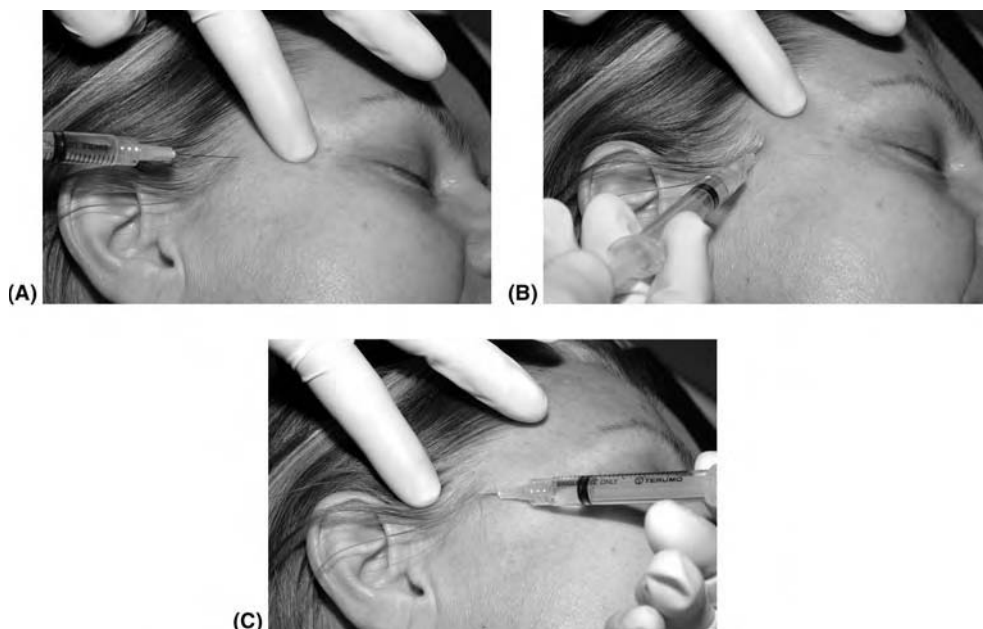


FIGURE 3 (A,B,C) Injection of botulinum toxin A in the temporalis muscle.

approximately 90% of the cases, the temporal region where the ZTBTN is compressed by the temporalis muscle occurring in approximately 80% of the cases, septal deviation and enlargement of the turbinates noted in approximately 70% of the patients, and the occipital trigger site where the greater and third occipital nerves are compressed that is seen in 38% of the patients.

The use of Botox has proved to be an extremely reliable prognosticator of the success of surgery. Botox itself has been observed to temporarily reduce the severity and frequency of MHs in numerous studies (23–29). The mechanism of action of Botox in alleviating headaches is not yet fully understood. We postulate that Botox, by virtue of paralyzing the offending muscle that irritates the underlying sensory (trigeminal and occipital) nerves, eliminates the trigger point, hence precluding the onset of MH pain. In the nose area, elimination of friction between a deviated septum and enlarged turbinates produces a similar outcome in the septum (30–33).

SURGICAL PROCEDURES

Frontal Trigger Site

After administration of appropriate systemic sedatives by the anesthesiologist and injection of local anesthesia (0.5% Xylocaine containing 1:100,000 epinephrine) in the upper eyelid and



FIGURE 4 Injection of botulinum toxin A in the semi-spinalis capitis muscle.

lower forehead, an incision approximately one inch long is made in each upper eyelid crease and is taken through the orbicularis muscle only. In the plane between the orbicularis muscle and orbital septum, the dissection continues cephalically until the frowning muscles (corrugator supercilii; depressor supercilii, and the procerus muscles) are exposed. The muscles are resected as thoroughly as possible, preserving and decompressing the supraorbital and supratrochlear nerves. Through the same incision, a small amount of excess fat, often protruding on the medial aspect of the upper eyelid, is removed and is applied to the muscle site to minimize the potential for a depression resultant from removal of the muscle and to shield the nerve branches. The fat graft is sutured in place using 6-0 Vicryl. The skin is repaired using 6-0 fast-absorbing catgut. During the recovery period, patients may observe some swelling and/or bruising and numbness in the forehead and orbital regions. This technique has been developed and reported by the author for aesthetic indications since 1992 and is now routinely used by many surgeons for elimination of frown lines (77). The patient can return to light activities the next day, routine activities in approximately one week, and strenuous activities in three weeks. There are no serious complications associated with this surgery, except for temporary forehead paresthesia. This procedure results in a notable aesthetic improvement in the forehead as well.

Temporal Trigger Site

After administration of appropriate systemic and local anesthesia, and with the patient in the supine position, the face is sterilely prepped and draped. The forehead, temple, malar region, and the scalp are injected with 1% Xylocaine containing 1:100,000 epinephrine for nonhair-bearing areas, while 0.5% of Xylocaine with 1:200,000 epinephrine is utilized for areas that are covered with hair. Four incisions, each 1.5 cm long, are placed approximately 7 cm and 10 cm from the midline, two on the left and two on the right side of the temple. The most lateral incision on the right side is made first using a 15 blade. A pair of baby Metzenbaum scissors is utilized to deepen the incision until the deep temporal fascia is exposed. Using a periosteal elevator, the dissection is conducted medially, laterally, cephalad, and caudally to accommodate the endoscopic access device. The periosteal elevator is used to dissect under the surface marking for the second incision, located approximately 7 cm from the midline. On this site, the dissection is conducted in the subperiosteal level. The endoscopic access device is then inserted in this incision. The periosteal elevator is used to raise the periosteum posteriorly and cephalically. The procedure is repeated on the left side. Under endoscopic visualization, dissection is continued along the lateral orbital rim to the malar arch and the malar region. The ZTBTN is exposed and avulsed by traction with a grasping forceps. As much length of the nerve as possible (usually 3 cm) is removed. This includes removal of the horizontal portion of the nerve. The proximal nerve end is allowed to retract into the deeper muscle to reduce the risk of neuroma. A similar procedure is performed on the opposite side. The endoscopic access devices are then removed. After placing a single hook on either side of the incision caudally, a 3-0 polydioxanone (PDS) suture is passed through the superficial and intermediate temporal fascia at the caudal portion of the most lateral incision, passing the needle from deep to superficial on one side of the incision, and superficial to deep on the other side of the incision. The skin hooks are then replaced along the posterior margins and the tissues are pulled laterally and minimally cephalically to increase the distance between the avulsed nerve ends, reducing the potential for reconnection. The suture is then passed through the deep temporal fascia and tied to minimize coaptation of regenerated nerve ends. A drain is inserted by passing it from one access incision to the other one on the opposite side. The drain is anchored in position and the incisions are repaired using a combination of 5-0 Vicryl and 5-0 plain catgut interrupted sutures.

The drain is removed within two days. The patient can return to routine activities in approximately one week, and strenuous activities in three weeks.

For patients who experience both temporal and frontal MH, the glabellar muscle group is removed through an endoscopic approach. The muscles are removed as thoroughly as possible and replaced with fat harvested from the supratemporal fossa (78).

Occipital Trigger Site

With the patient in a sitting position, a vertical incision approximately 4 cm long, confined to the hair-bearing skin, is marked in the midline caudal occipital region (Fig. 5). The patient is

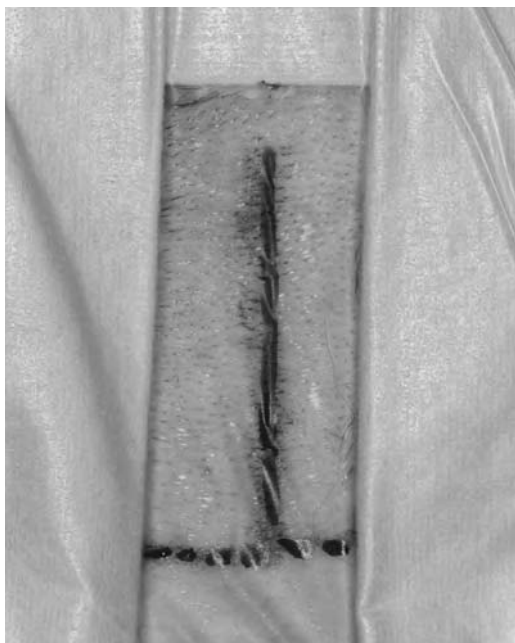


FIGURE 5 An incision is made about 4 cm in length in the midline occipital region.

then placed in a supine position, and appropriate anesthesia is induced. The patient is turned into a prone position once anesthetized. The shoulders are raised using soft padding, and the neck is flexed as much as possible, within safe limits. The occipital area and the upper cervical region are infiltrated with Xylocaine containing 1:200,000 epinephrine. An incision is made through the skin and taken through the subcutaneous tissues using coagulation cautery. The incision is deepened to the midline raphe (Fig. 6). At this level, the dissection diverges to the right side of the midline, and the trapezius fascia is incised. The vertical fibers of the semispinalis capitis muscle are located immediately below this fascia and can be identified while the trapezius

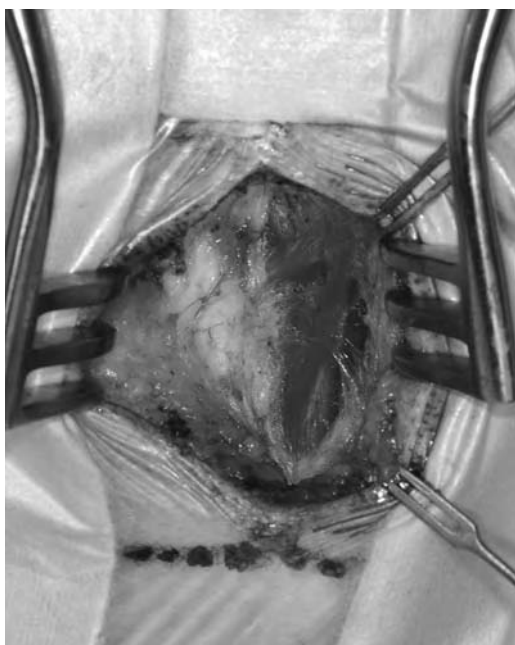


FIGURE 6 The incision is deepened off the midline to identify the vertical fibers of the semispinalis capitis muscle.

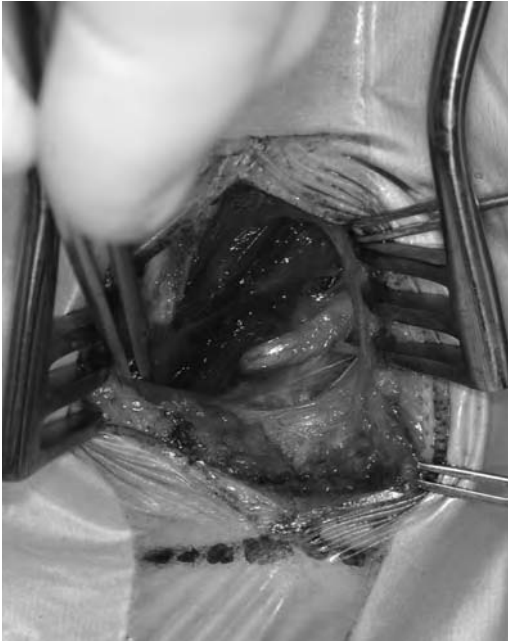


FIGURE 7 The greater occipital nerve emerges from the semispinalis capitis muscle approximately 1.5 cm from the midline and 3 cm caudal to the occipital protuberance.

fascia or, occasionally, the muscle with oblique fibers is pulled laterally. Retractors are used to expose the semispinalis capitis muscle. The dissection is continued laterally in the subfascial plane and superficial to the semispinalis capitis muscle.

Approximately 1.5 cm from the midline and 3 cm caudal to the occipital protuberance, the trunk of the greater occipital nerve can be identified (Fig. 7), emerging from the semispinalis capitis muscle and reaching the subfascial plane. Using a pair of munion clamps, the dissection proceeds between the nerve and the muscle fibers in a cephalocaudal direction. The munion clamp is then placed across the muscle fibers medial to the nerve caudally (Fig. 8). While the

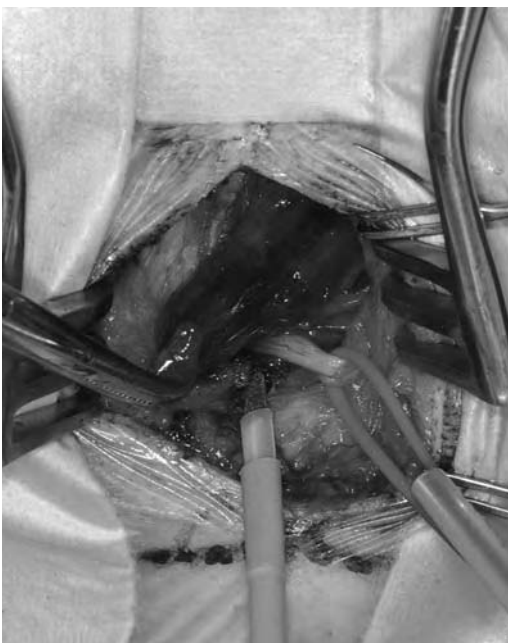


FIGURE 8 A munion clamp is placed across the muscle fibers medial and caudal to the nerve.

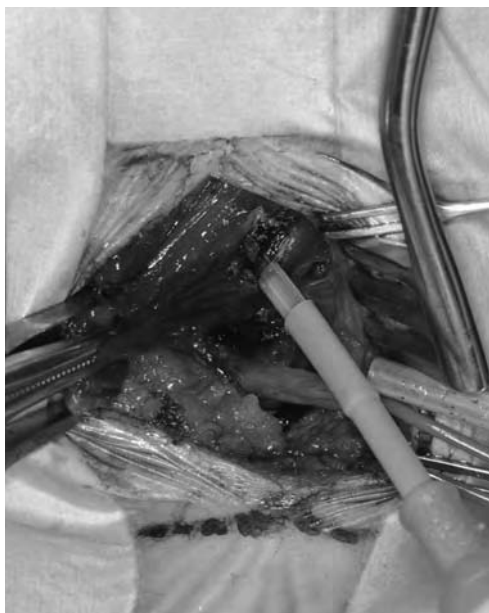


FIGURE 9 With the munion clamp lifted away from the nerve, the semispinalis capitis muscle fibers are transected caudally and cephalically.

munion is lifted away from the nerve, the full thickness of the semispinalis capitis fibers is transected caudally and cephalically (Fig. 9). A one-inch segment of muscle medial to the GON is removed. This procedure continues to the deeper layers until the nerve is completely uncovered and no muscle fibers remain medial to it.

A portion of the trapezius fascia and a small portion of the trapezius muscle overlying the GON rarely are routinely removed (Fig. 10). The GON is lifted away from the semispinalis capitis muscle utilizing a vessel loop placed around it. Any fascial bands encasing the greater occipital nerve are released, similar to a carpal tunnel release. The dissection continues laterally until the subcutaneous plane is reached. After assurance that the entire greater occipital nerve

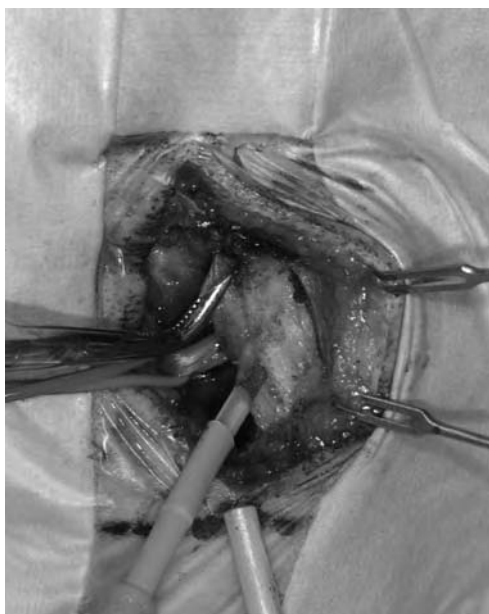


FIGURE 10 A portion of the trapezius fascia and a small portion of the trapezius muscle overlying the greater occipital nerve are removed.

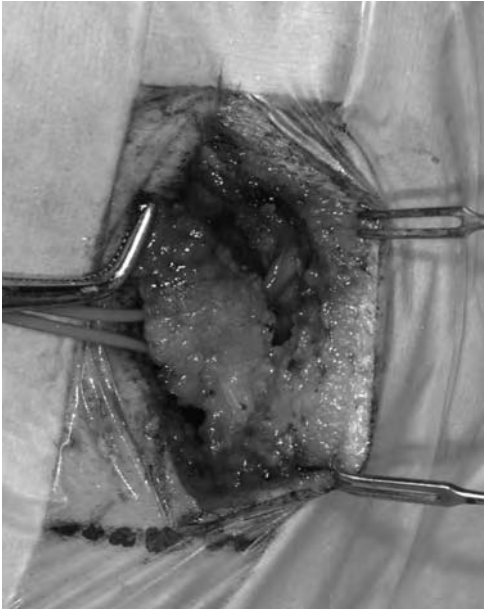


FIGURE 11 Elevation of a caudally base subcutaneous flap, approximately 2×2 cm, to be passed under the nerve.

is free on one side, the procedure is repeated on the opposite side. Should there be a bifurcation of the GON, which is not uncommon, any muscle existing between the branches are removed. If the nerve is found wrapped around the remaining fibers of the muscle, an additional pie-shaped segment of the muscle will be removed lateral to the nerve in order to avoid any undue tension or pressure on the nerve.

After the GON is released bilaterally, a caudally based subcutaneous flap, approximately 2×2 cm, will be elevated on each side (Fig. 11), rotated into position, passed under the nerve, and sewn to the midline raphe and deeper fascia lateral to the nerve (Fig. 12). This flap prevents reconstitution of any regenerating muscle fibers, and avoids the development of a ring of muscle

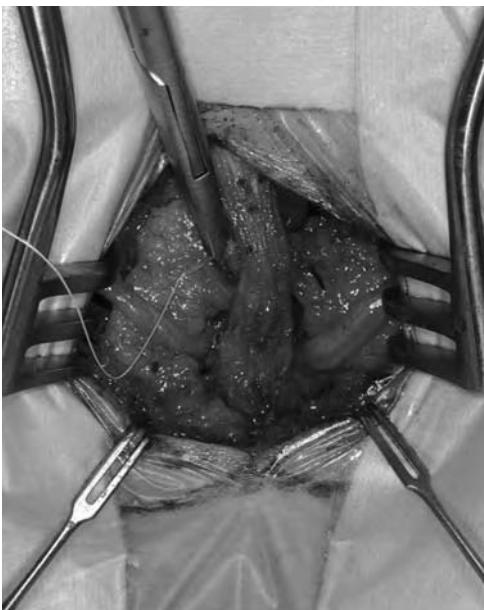


FIGURE 12 The flaps are passed under the nerves bilaterally and sutured to the midline using 4-0 Monocryl sutures.

around the nerve. The third occipital nerve is generally sacrificed during elevation of this flap, which is often beneficial. A suction drain is inserted, and the wound is closed in a manner that will completely eliminate the dead space using 5-0 Vicryl and 5-0 plain catgut. The drain is removed within two days. The patient can return to routine activities in approximately one week and strenuous activities in three weeks.

Intranasal Trigger Site

With the patient in a supine position under general anesthesia, the face is prepped and draped. The nose is packed with cocaine-containing gauze and infiltrated with Xylocaine containing 1:200,000 epinephrine. An L-shaped incision is made on the left side of the septum and the mucoperichondrium is elevated. An incision is then made in the septal cartilage and the opposite mucoperichondrium is elevated. The deviated portion of the cartilage and septum, the vomer plate, and perpendicular plates are removed. A straight portion of the septal cartilage is replaced. The flap is placed back in position and repaired using 5-0 chromic and running quilting sutures. A simple stent is placed on either side of the septum for a period of three weeks to reduce synechiae. Doyle stents are placed in position to help stabilize the septum in the desired position and fixed using 5-0 Prolene suture. The stents are removed in six to seven days. Generally, the patients can resume light activities the next day and more energetic exercises in one week. If necessary, the nasal spine will be osteotomized and repositioned along with the caudal anterior portion of the septum.

Should an enlarged inferior turbinate accompany the septal deviation, a conservative partial turbinectomy may prove necessary to provide sufficient space for the septum to be repositioned.

INFERIOR TURBINECTOMY

The inferior turbinates are infiltrated with Xylocaine containing 1:200,000 epinephrine. A conservative inferior turbinectomy is accomplished using turbinate scissors. The infracture is performed partially and the raw area is gently cauterized. Alternatively, this goal can be accomplished using a coablator set at 6 mJ for 10 seconds.

MIDDLE TURBINECTOMY

The middle turbinate is infiltrated with Xylocaine containing 1:200,000 epinephrine. The protruding portion of the middle turbinate is carefully isolated by elevation of the mucoperichondrium and removed, and the remaining raw surface is gently cauterized to minimize postoperative bleeding.

SUMMARY

This chapter describes the process by which MH trigger sites can be identified step-by-step by using a combination of symptoms, followed by injection of botulinum toxin and CT scan of perinasal sinuses. The trigger sites can be deactivated by surgical procedures designed to deal with specific sites. At those sites where the nerve is important enough to be saved, the muscles are resected (corrugator muscle group and small portion of the semispinalis capitis). At the sites where the muscles need to be preserved and the nerve is expendable [ZTBTN, third occipital nerve (TON), lesser occipital nerve (LON)] the nerve is sacrificed. Prior to the surgery, it is essential that every patient is evaluated by a neurologist to rule out the possibility of other diagnoses and the concomitant presence of other pathologic conditions that can be of more serious consequences, to lend more credibility to the surgical treatment. Plastic surgeons are not trained to treat MH and it is absolutely critical to approach these patients as a member of the treatment team.

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9 Management of Velopharyngeal Dysfunction

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THE PROBLEM: VELOPHARYNGEAL DYSFUNCTION

Velopharyngeal dysfunction (VPD) is the constellation of speech-production disorders that includes velopharyngeal insufficiency, incompetence, and incorrect learning. Anomalous velopharyngeal closure prevents appropriate speech production. Patients with VPD may present with hypernasality, nasal emission, or facial grimacing. In their attempt to be understood, affected patients often develop compensatory, maladaptive articulations that are very difficult to reverse if left untreated. Many times, this failure of the sphincteric mechanism is the result of a structural defect of the pharyngeal walls or the velum (soft palate) at the level of the nasopharynx.

Increasingly, speech scientists and surgeons have converted to using the term VPD in place of the older and more entrenched term, VPI (1,2). In common parlance, VPI generally means that there is incomplete sphincteric closure during production of oral sounds of speech. Use of the latter term, VPI, is confusing because various authors use it to connote "insufficiency," "incompetence," "inadequacy," or "incorrect learning." While such descriptors are used synonymously, they are not necessarily equivalent. In contrast, the term VPD does not assume or exclude any possible origin of speech symptoms. Anatomic, myoneural, behavioral, or combinations of disorders are all possible causes of the dysfunction. VPD occurs in approximately 20% of children who undergo palatoplasty (3). In depth evaluation of symptoms, causes, and treatment outcomes are critical aspects of managing patients with VPD.

Patients with VPD should be managed within in the context of multidisciplinary team care. In 1988, an international working group convened to standardize definitions and assessment methodologies (4). The working group strongly recommended implementing a multidisciplinary team approach and using multimodal instruments to evaluate preoperative and postoperative speech outcomes. The group asserted that comprehensive analysis of specific causes of speech production disorders, through perceptual and instrumental measures of velopharyngeal function, allows for customized treatment algorithms for specific patients.

ROLE OF THE SPEECH PATHOLOGIST

The surgeon, speech pathologist, and other health care providers work closely together to achieve the goal of optimal patient management. These practitioners collaborate in their review of the in depth diagnostic assessment results and the individual patient's medical history. Consensus evaluation usually provides an appropriate course of management for affected individuals, and may allow differential diagnosis to lead to differential management (5). Ideally, this means that care providers attempt to match gap size, shape, and velopharyngeal closing pattern to the most appropriate intervention.

Surgeons, as well as lay people, are usually capable of recognizing speech "differences." Perception of "difference" does not require a sophisticated understanding of speech physiology, but discrimination of the causes and severity/magnitude of that difference and treatment planning does. Speech and language pathologists are particularly adept at sorting out the components of a communication disorder and their respective weights, which frequently dictate *what* receives surgical attention, not *whether* it receives attention. This is both a skill and a talent that surgeons and lay people rarely possess.

THE RELATIONSHIP BETWEEN SPEECH PATHOLOGIST AND SURGEON

It is important to make the critical distinction between velopharyngeal-valve function (structural defect) and speech function. To use an analogy, if a newly licensed 16-year-old driver gets

in a car wreck, it is important to differentiate between mechanical failure of the car and failure of the just-learning driver to maintain control of the vehicle. Was the driver taking mind-altering drugs? Was it the car's fault or the driver's fault? The answers to these questions are basic to the investigational algorithm. They tell us where to look next, keeping in mind that both might have been at fault.

The same logic holds true for evaluation and management of VPD. Is it the velopharyngeal valve (car) at fault or the speech disorder (driver) at fault? The answer to this question tells us not only what to do next, but who is to do it. Treatment may involve fixing the velopharyngeal valve (surgeon) or teaching the driver (speech and language pathologists). Examining the velopharyngeal valve should be quite straightforward. Can the patient eliminate nasal escape? It is fairly easy to determine a yes or no answer by simple mirror test at the bedside. Diagnosis of hypernasality is much more difficult to evaluate. Using vocal, nonverbal testing can obviate such problems as phoneme-specific velopharyngeal insufficiency. An astute speech and language pathologist should be able to make the determination despite the confounding glottal stops, fistulae and so forth. We as surgeons should emphasize to parents, patient, and other providers that surgical success can be anticipated with respect to nasal escape and hypernasality. Then comes the speech and language pathologist's battle for speech and language success (articulation, and so forth).

ANATOMY

The anatomy of the velopharynx (palate, posterior pharyngeal wall, airway) is depicted in Fig. 1.

The composite movements of the lateral pharyngeal walls, the velum and posterior pharyngeal walls, close the velopharyngeal port in deglutition and during oral speech sounds; it opens the port for breathing and some nasalized articulations. Patterns of closure as observed on preoperative instrumental assessments include coronal, sagittal, bow tie, circular, and Passavant's (Fig. 2).

BASIC SPEECH TERMINOLOGY FOR THE SURGEON

Presumably, care providers representing the various disciplines of the cleft team use the same nomenclature so that they may organize and communicate their knowledge effectively. Trost-Cardamone (6) developed a useful taxonomy to classify possible causative factors of VPD.

In velopharyngeal insufficiency, there is insufficient tissue to accomplish closure of the velopharyngeal sphincter.

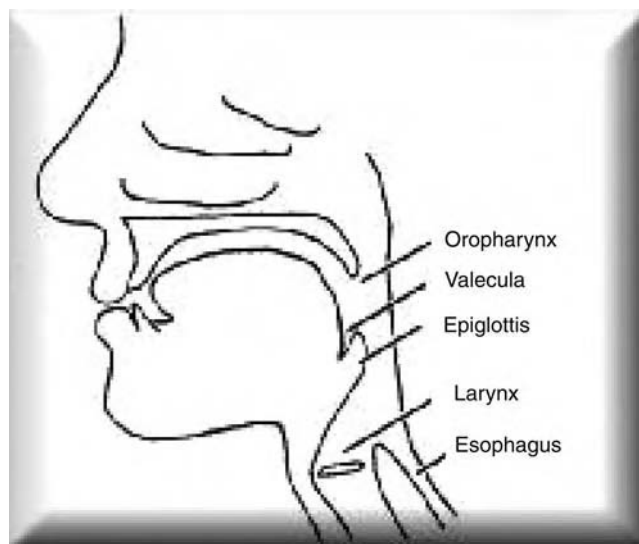


FIGURE 1 Schematic lateral view of the velopharynx illustrating anatomy.

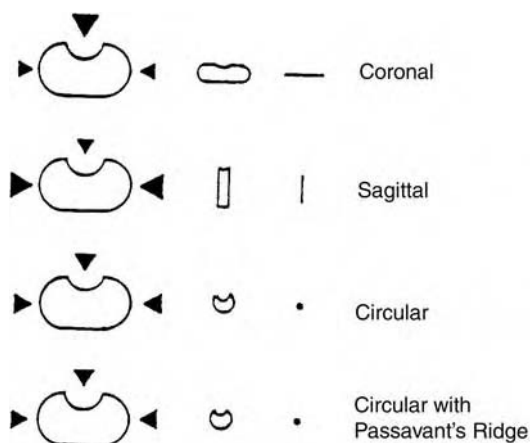


FIGURE 2 Schematic “bird’s eye” view of the velopharynx, illustrating directional movements of the representative closure patterns.

Additionally, velopharyngeal insufficiency occurs when structural etiologies exist, such as mechanical interferences with closure (including excessively large tonsils and/or webbing of the posterior tonsillar pillars) (7).

Velopharyngeal incompetence occurs with neurogenic etiologies, such as motor disorders.

Velopharyngeal incorrect learning may be the result of phoneme-specific nasal emission and deafness or hearing impairment.

Hypernasality and hyponasality are voice tones that are shaped by the mouth and oropharynx. Hypernasality is excessive resonance in the nasal cavity that is usually related to VPD because of a lack of barrier between oral and nasal cavities. While, hypernasality usually refers to velopharyngeal sphincteric function, it may be secondary to a fistula or unrepaired cleft palate.

A lexicon of additional terms that used to describe some elements of cleft palate speech dysfunction is provided in Table 1 (8,9).

HISTORY AND PHYSICAL EXAMINATION: FOCUS OF THE INITIAL CONSULTATION

When a patient is referred for surgical treatment of VPD, I try to elicit specific information germane to speech problems and/or cleft palate:

Questions

I try to ascertain from both parents and patient whether the speech-production disorder has caused psychosocial stigmatization, peer teasing, or frustration in not being able to

TABLE 1 Some Characteristics of Cleft Palate Speech

<i>Nasalance</i> : an acoustic correlate of nasal resonance, calculated as ratio of nasal to nasal plus oral energy.
<i>Airflow (nasal emission)</i> : different from nasal acoustic energy associated with hypernasality. Nasal instead of oral increase in airflow; Nasal emission and turbulence are disturbances of airflow mostly on production of pressure consonants.
<i>Nasal rustle, or turbulence</i> : is distracting, accompanies consonant production. Generally, small constriction in the nasopharynx produces a distinctive fricative sound. On the voiced pressure consonants b, d, and g.
<i>Hypernasality</i> : Nasally escaping air reverberating in a confined post nasal space.
<i>Grimace</i> : aberrant facial muscle movement subconscious attempt to inhibit the abnormal nasal airflow by constricting the nares.
<i>Hyponasality</i> : blocked up tone; may occur with nasal obstruction; enlarged adenoids, deviated septum, inadequate nasal airway, or chronic catarrh.

communicate with others. Nasal regurgitation of liquids or solids, and/or an associated hygiene problem may be the source of social embarrassment.

Findings

During intraoral inspection, I look for palatal fistulae, enlarged tonsils, visibly aberrant carotid pulsations along the posterior pharyngeal wall, a prominent adenoid pad, palatal zona pellucida (trough), palpable notch at the junction of the hard and soft palate, or a bifid uvula. I check for velar mobility (elevation) on speech tasks, and thus indirectly assess levator muscle status.

Provocative Tests

There are simple bedside maneuvers that can help define the speech problem. I carry a pocket size hand held mirror. This may be placed beneath the patient's nares in order to observe nasal airflow (audible air nasal emission). A straw may be placed at the corner of the patient's mouth while he/she recites a speech task. The listener at the other end of the straw perceives amplified air sound and/or unmasked hypernasality.

I listen to both spontaneous speech and structured provocative samples. Provocative samples of speech are designed to elicit phonemes requiring velopharyngeal closure. A representative sequence might include the following words or phrases: ma, ma, ma, puppy, puffy, muffin, pamper, sissy, go get a big egg, bye-bye Bobby, Katy likes cookies, Sally sees the sky. Production of voiceless consonants such as p, t, k, s, f, sh require maximal pulmonary pressures, and are thus a brief screen for integrity of plosive sounds. I try to ascertain overall intelligibility in running, spontaneous, connected speech. Patients with suspected VPD are incapable of achieving velopharyngeal closure on maximum effort, when producing properly articulated phonemes that require closure.

It should be emphasized that errors in these sequences of sounds should serve only as a "red flag" for the surgeon; interpretive significance of the errors should be left to the qualified speech and language pathologist. Most physicians are unfamiliar with the behavioral variables that can affect velopharyngeal function, such as oronasal discrimination proficiency, the presence of maladaptive articulations, the effects of coarticulation, range of articulatory motion, and the contribution of speaking effort. The speech evaluation should include attention to error types and "stimulability" of performance during visualization of dynamic speech activity. Arguably, it is the speech pathologist who best understands and interprets the movements and the articulatory and vocal structures.

I usually conclude my interview with extemporaneous hand-drawn pictures of the velopharyngeal mechanism to explain the complex speech mechanism to the patient and family.

AIRWAY EVALUATION

The tonsils and adenoids are often important components of the velopharyngeal closure mechanism. Occasionally, hypertrophic tonsils may herniate into the velopharyngeal port, so that lymphoid obstruction may actually be a source of speech dysfunction. Other times, enlarged tonsils may limit the technical placement of pharyngoplasty flaps, or their sheer size may efface the myomucosal pillars, making flap elevation difficult. Similarly, enlarged, friable, and hemorrhagic adenoids may inhibit performance of velopharyngeal surgery, and their presence may even compromise intervention outcome, if they contribute to flap dehiscence. In these circumstances, preoperative tonsillectomy and/or adenoidectomy may be indicated. This decision, however, must be made cautiously, in conjunction with the team otolaryngologist and speech pathologist. Tonsillectomy and particularly adenoidectomy should be avoided in any patient with symptoms of VPD until a differential diagnosis is established and a management plan is formulated by care providers and accepted by the patient and family. Clinical manifestations of VPD are likely to worsen after adenoidectomy. If it is necessary to perform adenoidectomy to facilitate technical execution of velopharyngeal surgery, the patient and family need to be duly warned about this predictable deterioration. I usually wait three months after adenoidectomy before proceeding with velopharyngeal surgery. It is wise to *personally* communicate with the team otolaryngologist to be certain he/she preserves the precious posterior tonsillar pillar tissue for later construction of the port.

INSTRUMENTAL ASSESSMENT OF SPEECH

Several diagnostic modalities assess speech production in patients who demonstrate symptoms of VPD. Detailed descriptions of these modalities are found in published articles (10). These modalities include video-recorded standard perceptual speech screenings (acoustic evaluation of sounds or listener judgments), such as nasendoscopy, nasometry, aerodynamics, and/or fluoroscopic speech evaluations. The studies have the advantage of being readily archived on digital media for review/study/strobe analysis, and so forth. Usually, the interdisciplinary velopharyngeal staffs of specialists, including a speech and language pathologist, otolaryngologist, prosthodontist, and plastic surgeon, review the test results.

If cephalometric evaluations are available, they can facilitate diagnosis. Tracings can quantitatively assess the: velar-length to velopharyngeal-depth ratio, which is often a good predictor of patients who require physical management of the velopharynx.

MANAGING VPD

Nonsurgical and Treatment Options

In a small number of cases, prosthetic management may be the best solution for treatment of VPD. Prostheses include:

- Palatal lift: (Figs. 3 and 4) Good for patients with adequate tissue but poor control of coordination and timing of velopharyngeal movements.
- Speech bulb/obturator: An acrylic mass used for closing residual velopharyngeal gaps to achieve closure when there is inadequate tissue.

Prostheses may be used as a temporary “reversible trial,” by providing diagnostic information in patients with variable VPD in whom it is unclear whether surgery alone will provide significant improvement in speech quality. A prosthesis may be useful in some patients with a short, scarred velum; or in other patients with a long supple parietic velum. Some authors



FIGURE 3 Palatal lift, showing hard and soft palatal components.

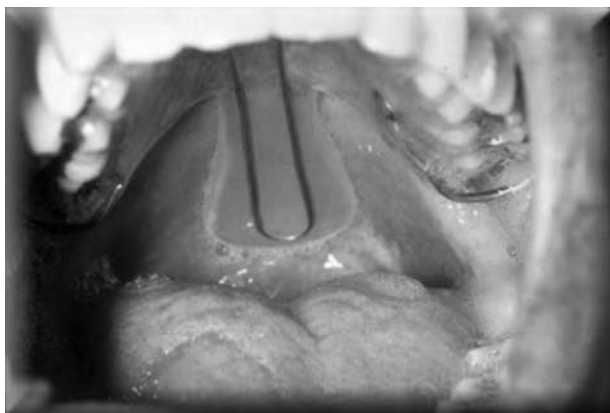


FIGURE 4 Palatal lift in situ.

have hypothesized that prostheses may stimulate neuromuscular activity (11) although definitive proof for this is lacking (12).

CONTRAINDICATIONS TO SURGERY

Velopharyngeal narrowing procedures are not appropriate for patients who meet the following criteria:

- Patient declines surgical management by choice.
- Patient has known or suspected risk for potential airway obstruction.
- Patient has intermittent or inconsistent closure that responds well to speech therapy.
- Patient has incomplete diagnostic results. With further studies and improvements in diagnostic technologies, speech production disorders should be more accurately assessed and individually managed to achieve optimal results.

I do not believe that visible pulsations on the posterior pharyngeal wall, indicating aberrant carotid arteries, should be an absolute contraindication to surgery (13).

WHAT ABOUT ABERRANT CAROTID ARTERIES?

Anomalous internal carotid arteries have been shown to be a frequent feature of velocardiofacial syndrome. These vessels pose a potential risk for iatrogenic injury and hemorrhage during velopharyngeal narrowing procedures. Various forms of cervical-vascular imaging studies such as computed tomography or angiography have been advocated as aids to surgery by defining the preoperative vascular anatomy. Nevertheless, it remains unclear whether these studies alter either the conduct or outcome of operations on the velopharynx. Iatrogenic injuries to the carotid artery during velopharyngeal surgery are strikingly absent in the extant literature. Occasionally, transmission of vascular pulsations through “floppy” redundant mucosa may artificially masquerade as an ominous vessel. Additionally, tortuous mesially displaced vessels observed at one point in time have been shown to straighten out laterally on later studies.

How should the surgeon approach the problem of aberrantly located carotid vessels? This is a provocative and controversial question that deserves overt answers from each participating surgeon, but safety must prevail as the first priority. When displaced vessels are identified, surgeons are faced with a few options: (i) the surgeon may abandon the procedure; (ii) the surgeon may “operate around” the vessels; (iii) the surgeon may choose to perform one procedure instead of another; that is, sphincter pharyngoplasty instead of pharyngeal flap (theoretically, performance of the latter procedure could expose a vessel over the full length of the flap).

I am personally comfortable operating in the presence of these aberrant structures, provided that I can reposition the flap(s) so as not to interfere with their presence, expose the vessel to oropharyngeal secretions, or compromise the execution of the procedure. I do not routinely obtain preoperative vascular imaging studies on all patients. In performing more than 150

velopharyngeal narrowing procedures, I have not been compelled to abort a single procedure. Awareness of their presence comes from careful inspection of the small operative field, palpation of aberrant vessels intraoperatively, and cautious surgery.

SURGICAL PROCEDURES FOR VPD

Partial obstruction, either temporary or permanent, of the velopharyngeal port is the unifying feature of most current operative management of VPD. There are two broad categories of options for VPD that depend upon the patient's specific diagnosis: (i) lengthening the palate by retropositioning the velum [this is purported to result from a V-Y pushback procedure, an intravelar veloplasty (14), or double opposing Z-plasty) (15) and] palatal re-repair (16) and (ii) reduction of the static opening between the nasal and oral pharynges (17,18). The latter, velopharyngeal narrowing procedures, may be accomplished with a pharyngeal flap, or sphincter pharyngoplasty. The pharyngeal flap creates a single subtotal central obstruction of the velopharyngeal port, leaving two open ports laterally. Alternatively, sphincter pharyngoplasty may be performed to diminish the cross-sectional area of the central port. Posterior pharyngeal wall augmentation is another method of treating resonance disorders and this procedure is used in various centers around the world with variable success. This chapter focuses primarily on pharyngeal flap and sphincter pharyngoplasty procedures.

CANDIDATES FOR PHARYNGEAL FLAP

It is known that lateral wall motion is important for effective valving after pharyngeal flap surgery (19). Performance of pharyngeal flap is most effective in patients with satisfactory lateral pharyngeal wall movement and sagittal or circular velopharyngeal closure patterns.

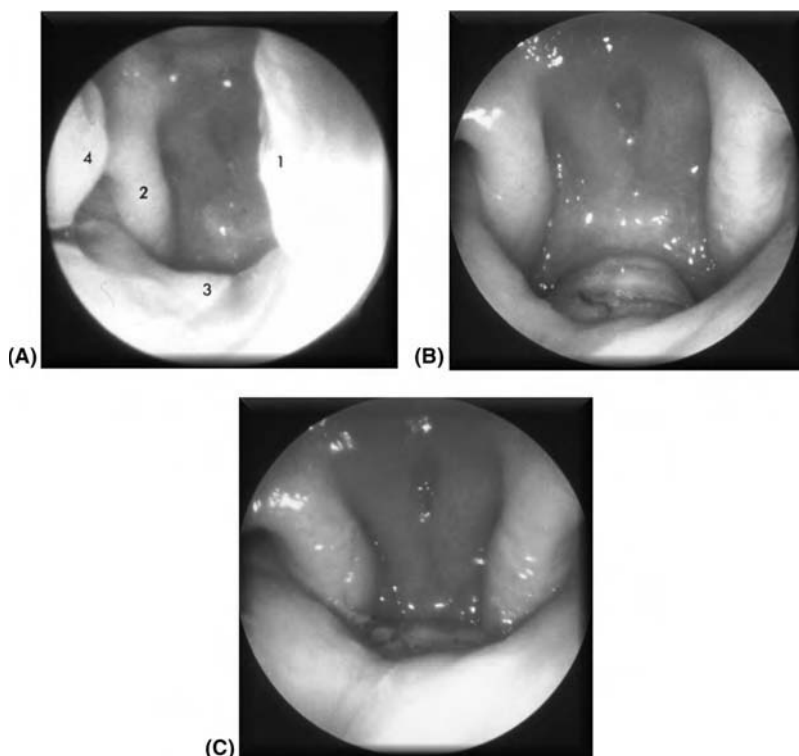


FIGURE 5 (A) Preoperative nasendoscopic view of the velopharynx. 1,2=lateral pharyngeal wall; 3=velum; 4=tonsil. (B) Postoperative nasendoscopic view of velopharynx, indicating open pharyngeal flap as central subtotal midline obstruction; two patent velopharyngeal ports are visible laterally. (C) Postoperative nasendoscopic view of velopharynx, indicating two lateral pharyngeal walls opposed against pharyngeal flap to affect complete velopharyngeal closure.

The objective of the pharyngeal flap is to create a central static obstruction and to leave two lateral ports or openings, termed pharynges (Fig. 5).

Lateral openings should remain patent during breathing and nasal consonant speech production and closed during the production of oral consonants.

Schoenborn originally published a description of this procedure in 1876 (20). The pharyngeal flap was widely adopted in the 1950s and has been studied fairly extensively.

DIFFERENT KINDS OF PHARYNGEAL FLAPS

The pharyngeal flap has been widely modified, and variations in specific techniques abound. Key questions stimulating the development of these modifications include the following: What is the appropriate width of the pharyngeal flap? Is a superiorly- or inferiorly-based flap more effective in achieving the ideal outcome? Should the flap be lined with mucous membrane to prevent postoperative contraction/attenuation of the flap?

WHAT IS THE APPROPRIATE LEVEL AND WIDTH OF PHARYNGEAL FLAP?

Determination of level of insertion and flap width may influence proper closure of the new lateral ports during speech. An excessively wide, nearly obstructive flap may induce untoward secondary consequences (i.e., mouth breathing, hyponasality, sleep disturbances ranging from snoring to sleep apnea, and retention of nasal secretions and mucus). Hyponasality may persist if the flap is too long and thin. Historically, flap width is determined at the time of surgery by the surgeon's experience or preference. Many surgeons attempt to create a flap as wide as the field allows.

LINING THE PHARYNGEAL FLAP

If the flap is unlined, a broad, raw surface of pharyngeal tissue is left exposed after its elevation. Subsequent contraction (healing by secondary intention of unfulfilled mucosa) may diminish its efficacy. Thus, initial postoperative results may indicate improvement in velopharyngeal function, yet symptoms of the dysfunction may recur gradually thereafter. To reduce the tendency for contraction, "book flap" linings usually are raised from the nasal surface of the posterior velum and folded over to cover the unfulfilled surface of the flap (Fig. 6A-I).

LEVEL OF FLAP INSET AFFECTS OUTCOME

The level of flap insertion is linked to surgical success. Insertion of a short, wide flap along the free margin of the soft palate may reduce the contraction of unlined flaps. Placing the flap at this level theoretically narrows the gaps between the base of the flap and the attached tonsillar folds where they merge with the pharyngeal wall. Presumably, this creates a velopharynx that is nearly completely obstructed and requires little contribution of movement from the lateral pharyngeal walls to achieve closure.

CAN LATERAL PORT SIZE BE CONTROLLED?

Hogan (21) devised a surgical technique to modulate the postoperative port size. He introduced the concept of lateral port control in the 1970s, using indirect information of the size of the velopharyngeal port from differential nasal and oral airflow. Studies by Ishiki and Warren, Warren, and Devereau corroborated this hypothesis and demonstrated that port size is related to the perception of nasal resonance (22,23). Kummer has recently extended this concept (24).

Hogan's technique involves placement of 10mm² catheters that he assumed to be the crucial variable for anticipated normal resonance. Although this technique may seem intuitive and logical, other uncontrolled variables such as the vagaries of wound healing, scarring and postoperative migration of the flap lead me to believe that port size cannot always be rigorously and reliably controlled.

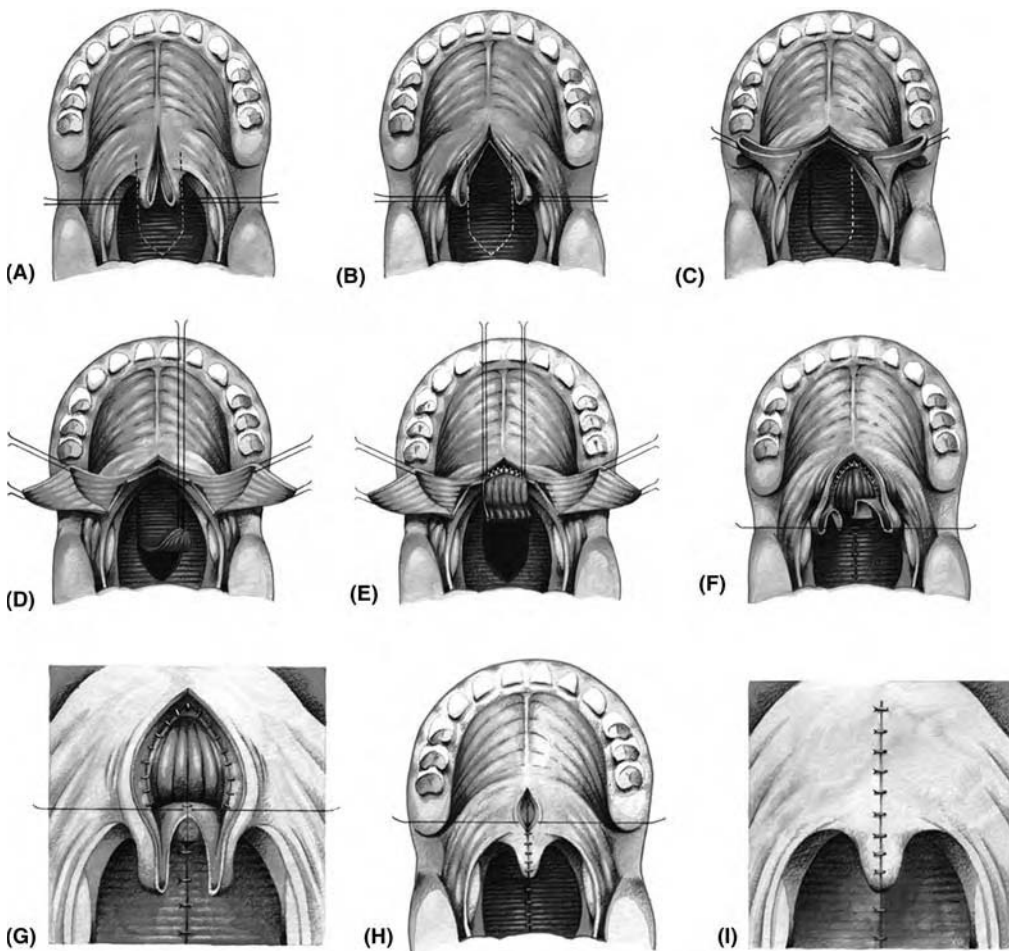


FIGURE 6 (A) Sutures are placed bilaterally in the soft palate to enhance visualization. A midline incision divides the soft palate to the posterior nasal spine. (B) Soft palate flaps are retracted. (C) An incision is made along the dotted line on the posterior pharyngeal wall down to the prevertebral fascia. A pharyngeal flap is created. A book-flap incision that will line the lateral ports with mucous membrane is then made bilaterally on the nasal surface of the soft palate. (D) Pharyngeal flap is plotted with indelible ink and elevated to the prevertebral fascia. Two soft palate flaps are opened laterally. (E) The free inferior edge of pharyngeal flap is sutured to the posterior edge soft palate. (F) Sutures are placed between the pharyngeal flap and the nasal edges of the soft palate. The raw surfaces arising from the origin of the pharyngeal flap are closed by simple approximation of tissue. (G) Two flaps from the soft palate used to cover the raw tissue of the pharyngeal flap are sutured to the base of the pharyngeal flap. (H) Oral side of the soft palate is sealed to conceal the pharyngeal flap. (I) Immediate postoperative view from the oral cavity.

CAN SPECIFICATIONS OF THE PHARYNGEAL FLAP BE TAILORED TO PATIENT'S NEEDS?

It remains unclear whether appropriate flap width can be determined intraoperatively on a routine basis. In most cases of postpalatoplasty VPD, control of the flap width based on the morphology observed during the operation is ineffective. However, it seems logical in cases of gross asymmetric closure patterns to focus on correcting that asymmetry (25,26). For example, patients with VPD secondary to hemifacial microsomia, stroke, or tumor resection may need specific skewing (tailoring) of flaps to affect closure.

BASING THE FLAP SUPERIORLY OR INFERIORLY

Whether the inferiorly- or superiorly-based flap has been the subject of lively debate among surgeons over the years, yet proof of significant differences between the two types is hard to come by (27). Currently, most surgeons favor a superiorly-based flap. The disadvantages of an inferiorly-based flap include length limitation and inferior tethering of the flap below the palatal plane and in the opposite direction of necessary motion for affecting velopharyngeal closure (28). Extrapolating from the information on failed sphincter pharyngoplasties, in which low flap placement correlated with failure, superiorly-based pharyngeal flap is preferred (29).

A fairly recent modification of the pharyngeal flap is the so-called lined pull-through procedure (30). This involves demucosalization of the oral surface of the posterior soft palate, which juxtaposes with the raw surface of the elevated pharyngeal flap. I do not believe this is a sound operation. In my experience, it results in substantial downward migration/tethering, and antagonizes normal velopharyngeal movement.

SPHINCTER PHARYNGOPLASTY

The goal of sphincter pharyngoplasty is to narrow the central velopharyngeal orifice, thus minimizing airflow through the nose during speech. Theoretically, sphincter pharyngoplasty tightens the central orifice without creating lateral ports, resulting in an opposite configuration of the velopharynx compared to the pharyngeal flap.

Sphincter pharyngoplasty was first described more than 50 years ago, yet only recently has become a procedure of choice among many surgeons. Because of insufficient collation of data, a detailed description of risks, benefits, and long-term outcomes has not been confirmed. The original concept of sphincter pharyngoplasty was described by Hynes (31) and has been modified by others, including Orticochea (32). The procedure rearranges palatopharyngeus myomucosal flaps raised from the posterior tonsillar pillars, which are transposed to the posterior pharyngeal wall and to each other. This procedure may result in less airway morbidity than the pharyngeal flap (33) and conceptually is more physiologic, although these impressions reflect my personal bias and remain unproven.

CANDIDATES FOR SPHINCTER PHARYNGOPLASTY

Sphincter pharyngoplasty may be an appropriate management option for patients with VPD who would not be treated with speech therapy alone and whose nasendoscopic evaluations indicate a large-gap, coronal, circular, or bow-tie pattern of closure. Essentially, patients who demonstrate good velar elevation but poor lateral wall motion are good candidates for sphincter pharyngoplasty.

OPERATIVE TECHNIQUE

Pass a red rubber catheter transnasally and suture it to the uvula, and reflect the velum into the nasopharynx to achieve exposure of the posterior pharyngeal wall (Fig. 7A). Inspect the posterior pharyngeal wall for pulsations of aberrant carotid arteries. Next, plot lines of incision with indelible ink on both the anterior and, with the aid of a retractor, posterior aspects of the posterior tonsillar pillars, identifying the proposed myomucosal flaps (Fig. 7B). Infiltrate local anesthetic for hemostatic purposes.

Beginning on the right and then repeating the same maneuver on the left, raise the posterior tonsillar pillar as a myomucosal flap, based cephalad (Fig. 7C). Elevate lateral palatopharyngeus myomucosal flaps to the height of attempted velopharyngeal closure, as documented on the preoperative speech video fluoroscopy.

Incise the posterior pharyngeal wall transversely at the proposed area of insertion in conjunction with the cephalad extent of the elevation of the flaps. The continuous cut extends from the superior end of the posterior limb of one lateral flap to the other and allows the lateral flaps to be fully inset. This design eliminates the bilateral fistulae inherent in Orticochea's original construction. Lay all sutures in sequence and subsequently secure from cephalad to caudad. Remove red rubber catheter before securing knots.

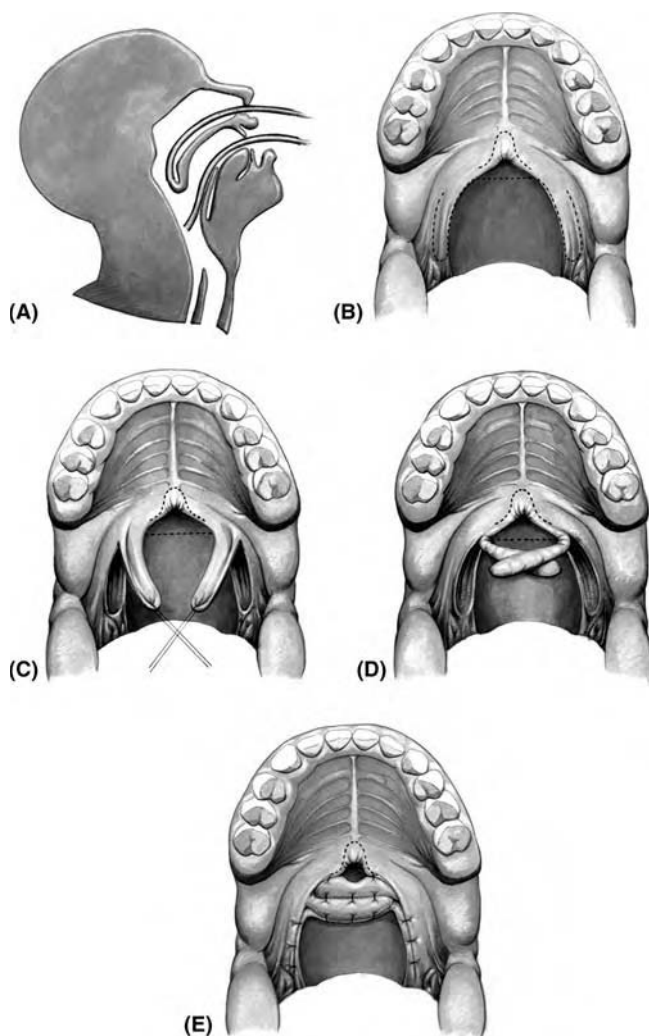


FIGURE 7 (A) Schematic of lateral view. Catheter has been passed transnasally and attached to uvula. (B) Schematic showing proposed incisions (*dotted lines*). (C) Schematic showing elevation of both tonsillar pillar flaps. (D) Schematic showing rotation of palatopharyngeal flaps through 90 degrees; ready for attachment to posterior pharyngeal wall. (E) Schematic showing completed sphincter pharyngoplasty. Flaps are overlapped, sutured to each other and posterior pharyngeal wall.

Attach superior mucosa of the left flap to the mucosa of the superior incision of the posterior pharyngeal wall. Attach the caudal mucosa of the left flap to the superior mucosa of the right flap, overlapping the two flaps as described by Hynes. Attach the caudal mucosa of the right flap to the inferior mucosa of the posterior pharyngeal wall (Fig. 7D).

Assist integrity of the newly created sphincter by suturing the lateral flaps securely to one another and to the superior constrictor and pharyngobasilar membrane. Attempt to capture the mucosa, submucosa, and epimysium with each stitch to maximize its holding power. Approximate tissues without tension, and close donor sites. Suture with 4-0 polyglactin. After construction of sphincter pharyngoplasty, place an orogastric tube, aspirate gastric contents, and remove the tube.

The central orifice of the sphincter pharyngoplasty port at the conclusion of the procedure should admit a small finger breadth (about 1 cm in diameter). A “tight” sphincter pharyngoplasty port usually measures approximately 0.5 cm in diameter, and a “loose” sphincter pharyngoplasty port usually measures approximately 1.5 cm in diameter.

LONG-TERM OUTCOME OF SPHINCTER PHARYNGOPLASTY

Riski demonstrated that the height of insertion appears to be a critical factor for success. He documented the emphasis on the importance of inset height for placement of the myomucosal flaps. In a follow-up study, Riski reported results in a large number of patients over a 15-year span (34). Results showed a high success rate among patients who underwent sphincter pharyngoplasty before speech dysfunction developed fully. Success also seemed to correlate with patients who were younger than six years at the time of operation.

Witt (35) a study in which preoperative speech and instrumental assessments were separated to provide perceptual information and physiologic relationships. Only 18% of the patients involved in the study showed 100% resolution of hypernasality and nasal emission. Approximately, 30% of the patients developed hyponasality and/or obstructed speech and breathing patterns. Sphincter pharyngoplasty remains an effective treatment modality for VPD; however, the study does emphasize the need for further comparative data.

POSTOPERATIVE CARE

Patients are monitored overnight with pulse oximetry and oxygen by nasal canula. They may resume a soft or liquid diet immediately. Most patients are discharged from the hospital after one night, although patients with 22 q 11 deletion often require at least two nights in the hospital. I see patients three weeks after surgery for followup. In the meantime, parents are given information about sleep apnea and breathing signs to watch for. Our team nurse communicates with parents by telephone. I assume that a highly integrated and focused program of speech therapy will resume three to six weeks after surgical VPD intervention.

COMPLICATIONS

Risks involved with surgical VPD treatment include acute obstructive sleep apnea, dehiscence (failure of procedure), and a potential/theoretical risk of iatrogenic injury to anomalous internal carotid arteries.

Sleep disturbances as a consequence of sphincter pharyngoplasty may range from simple snoring to acute obstructive sleep apnea. Rarely is sleep apnea so severe as to require hospitalization. This adverse effect appears to occur in a substantial percentage of patients surgically managed for VPD, as suggested in a preliminary report by Witt in which the incidence was 13% of 58 patients observed. (33)

Complete nasopharyngeal obstruction should be a rare complication, assuming that all raw surfaces were properly fulfilled at primary pharyngoplasty. I have not encountered it in my practice. I have seen patients in referral who presented with the unhappy triad of sleep apnea/snoring, hyponasal resonance, retained secretions/maxillary sinusitis (Fig. 8).

Velopharyngeal surgery is still more of an art than a science. The goal is to create a subtotal obstruction that improves resonance, but avoids airway morbidity. Still, in about 10% of cases, reoperation is necessary to treat residual hypernasality or nasal emission.

AXIOMS

- A finite number of patients will develop VPD, regardless of surgeon experience, palatoplasty technique, timing of operation, early speech therapy intervention (36,37,38).
- Make sure the patient is managed by a team of specialists.
- Midface advancement may affect velopharyngeal function, particularly those with borderline function.
- Patients with 22 q 11 microdeletion (velocardiofacial syndrome) are notoriously difficult to manage (39,40,41); parents need to be counseled carefully, usually on repeat occasions preoperatively, to temper their expectations about intervention outcome.
- Removing enlarged tonsils three months prior to velopharyngeal surgery makes your job easier.
- Place pharyngoplasty flaps at least as high as the atlas (C1), or higher if that is the place of attempted velopharyngeal contact as noted on preoperative speech videofluoroscopy.



FIGURE 8 Complete nasopharyngeal stenosis.

- You should *not* be able to see a well-placed pharyngeal flap on intraoral inspection postoperatively.

COMPLEX PROBLEMS ASSOCIATED WITH VPD RESEARCH

Several studies have been published in support of each of the available options for management of velopharyngeal insufficiency; however, most of the data have not been validated by large numbers of patients, nor have these results been subjected to critical analysis. Most of these studies lack a multidisciplinary evaluation, standardized evaluation/treatment criteria, and methods for assessing surgical outcome.

For example, several different types of sphincter pharyngoplasties have been described, although commonly, they have been grouped together as though they were the same. These procedures differ regarding transposition of the flaps, use of muscle tissues, the levels of insertion, and whether a synchronous pharyngeal flap is used. Other uncontrolled variables include status of tonsils, and whether a full thickness transverse cut in the posterior pharyngeal wall mucosa is made. This heterogeneity of sphincter pharyngoplasties explains some of the difficulty in describing postoperative outcomes.

There is inherent instability of cleft palate populations, migratory patterns of treating physicians; and dogmatism among surgeons regarding the “best technique.” Additionally, the study designs often do not include rigorous documentation of the preintervention, periintervention, and post intervention states; or the methodology for evaluation of the intervention. It is an arduous task to achieve a high compliance rate from a patient population stratified for age, sex, socioeconomic factors, and number of surgical interventions. The outcome assessment instrument must be designed to allow analysis of intra- and inter-rater reliabilities of all the extramural raters, and at the same time not be so cumbersome and burdensome as to reduce compliance.

FUTURE DIAGNOSTIC/ASSESSMENT/TREATMENT MODALITIES

There are exciting new technologies on the horizon, such as dynamic magnetic resonance imaging of the velopharynx that soon may be available for clinical use. Magnetic resonance data can be reformatted to simulate endoscopy. Planar images may be converted to three-dimensional volumes. While in its infancy, this technology may someday allow clinicians feel as if they can actually go inside the anatomic structures they have scanned with “fly throughs,” focusing on specific pathologies. This has the potential of evolving into non-invasive endoscopy, assuming that it can meet or exceed the gold standards currently available (42).

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10 | The Lacrimal Outflow System

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ANATOMY

The punctum is a funnel-shaped structure surrounded by a ring of connective tissue that is approximately 0.2 to 0.3 mm in diameter. The upper and lower puncta open on a slight elevation of the posterior margin of the lid corresponding to the junction of the cilia and lacrimal portions of the lids. Inferior to the punctum is the vertical component of the canaliculus, which is 2 mm in length and 1½ to 2 mm in diameter. The canaliculi lie within the eyelid margin and proceed medially for 8 mm and then join, in most cases, the common canaliculus, 3 to 5 mm in length, which empties into the lacrimal sac at the junction of its upper third and lower two-thirds (Fig. 1). The common internal punctum may have folds of tissues surrounding it acting as a valve that may prevent decompression at the lacrimal sac in cases of mucocoele or pyocoele.

The lacrimal sac rests on the periosteum lining the bony lacrimal fossa and is covered by a firm fascial extension of the periosteum. The frontal process of the maxilla anteriorly and the lacrimal bone posteriorly form the lacrimal fossa. The position of the lacrimal fossa is comparable to the middle meatus of the nose with the upper portion contiguous with the anterior ethmoid air cells. In some cases the ethmoid air cells may extend sufficiently anteriorly and inferiorly to be between the lacrimal fossa and nasal cavity. The fundus of the sac extends superiorly posterior to the medial canthal ligament. It is the relationship with the medial canthal ligament that causes abscesses or fistulas to appear in nearly all cases below the inferior border of the tendon. Swelling above the tendon suggests tumor rather than inflammatory disease.

The nasolacrimal duct is formed by a continuation of the sac inferiorly to where it enters the nose at the inferior meatus. The nasolacrimal canal, through which the nasolacrimal duct passes, is 12 mm in length. The approximate distance from the external naris to the opening of the duct in an adult is 30 to 35 mm. A form of mucous membrane, the valve of Hasner, is present at the opening of the duct and functions to prevent reflux of air or nasal discharge into the nasolacrimal system. There are folds of mucous membrane, which act as valves within the sac. These probably have little effect on tear flow.

Infectious processes involving the lacrimal excretory system are influenced by the juxtaposition of the lacrimal sac to the orbit, sinuses, and nose with resulting multiple possibilities for obstruction of flow and stasis. Infection within the sac is, in most cases, dependent on obstruction of flow and, in rare instances, can be related to foreign body or intrasac tumor growth. The canaliculus can also develop infection; however, this is less related to obstruction. The juxtaposition of the sac to the ethmoid and maxillary sinuses and the orbit leave it prone to external compression or associated inflammation with pathologic processes involving these structures. The necessity for the nasolacrimal duct to drain into the nose leaves it vulnerable to nasal pathology that could obstruct the opening at the valve of Hasner. Conjunctival and lid disease can adversely impact the function of the punctum and canaliculus with the possibility for secondary infection.

Iatrogenic causes of lacrimal outflow obstruction include nasal or sinus surgery that can lead to cicatrix formation in the area of Hasner's valve. Medial canthal reconstruction risks canalicular compromise and orbital implant materials can impinge on the lacrimal sac. Trauma to the midface impacts on the lacrimal system. The sac and nasolacrimal duct are relatively protected from injury by low velocity trauma. However, naso-orbital-ethmoid (NOE), maxillary and complex Le Fort fractures, frequently occurring as the result of high velocity injuries, cause comminution, rotation, compression, and shearing forces on the skeletal support of the lacrimal system.

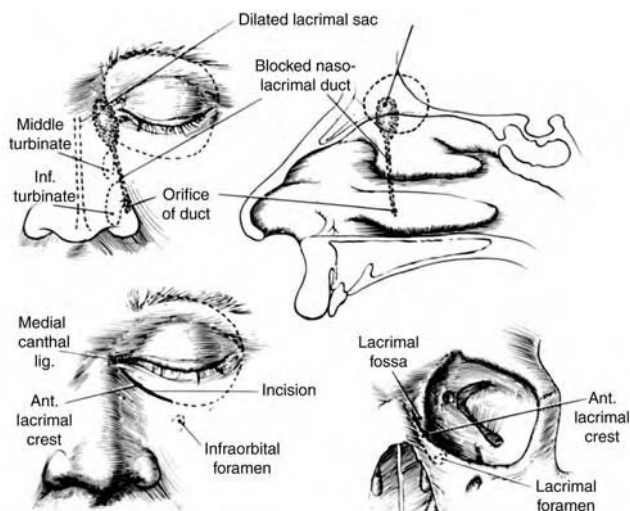


FIGURE 1 Anatomy of the lacrimal outflow system. *Abbreviations:* Ant., anterior; Inf. inferior; lig., ligament. *Source:* From Ref. 158.

HISTORY

Infection in the area of the lacrimal sac is mentioned in the Code of Hammurabi in the second millennium B.C. Inflammation was described as occurring at the nasal canthus with subsequent rupture of the sac and fistulization (1). From the earliest times, the gross manifestation of lacrimal abscess and fistula on the face lead to reports suggesting a “rotting of the naso-orbital bones or drainage from the brain.” In the middle of the first century A.D., Versalias and Fallopias presented a reasonably accurate description of the lacrimal system (2). In the second century A.D., Galen proposed the caruncle as the cause for blocking tear secretion and followed by lacrimal fistulization, and the focus on the caruncle as the cause of the problem continued through the Middle Ages. At the first part of the 18th century Maitre ([^] over the i), Jean first suggested that tears and secretions (which he felt were secreted by the sac) caused abscess when stasis occurred (1). It was not until Stahl, in 1702, wrote on the pathologic manifestations and described acute, chronic, and ulcerative afflictions of the nasolacrimal canal that the concept of inflammation of the canal was as the basis for the disease was advanced (2). In the latter part of the 19th century, Peters showed that neonatal dacryocystitis was as a result of blockage of the lacrimal ostium (1).

First treatment of abscess in the lacrimal sac consisting of rubbing the eyes with a mixture of honey, antimony, and wood powder was described in the Ebers Papyrus approximately 1150 B.C. Pliny the Elder (23–29 A.D.) described a treatment with the herb *Aegylopsia fatua*, or wild oat, and at about the same time Celsus recommended opening the fistula to the bone and cauterizing the bone with a hot iron. Galen, in the second century A.D., also described the use of grapevine ashes, aegylopsia juice, vinegar, honey, and carob for the treatment for sac infection. Al-Ghafiqi of Cordoba described probing of the lacrimal fossa and perforation of the lacrimal bone in the 12th century A.D. But it was not until 1710 that irrigation through the puncta, comparable to what is currently done, was introduced by Anel. Pallucci in 1762 used linen thread to provide a stent to maintain patency, and, in the 19th century ophthalmologists used copper and platinum wires for the same purpose. Dacryocystorhinostomy (DCR) was described by Toti in 1904 and modified in 1921 by Depuys-Dutemps and Bouguet and improved versions of the same technique are still the basis of lacrimal surgery today (1).

THE LACRIMAL CANALICULAR SYSTEM

Trauma

Laceration of the lacrimal canaliculi is a relatively frequent sequellum of eyelid trauma. The weakest portion of the lid is that containing the canaliculus; thus avulsive forces to the lid tend to cause a tear through the canaliculus.

Acute intubation with silicone of this type of injury offers a reasonable success rate (50–80%) (3,4) that is considerably better than that which can be achieved by later reconstruction. This is a situation, therefore, in which acute intubation of the lacrimal system should be considered. It follows that it is important that a canalicular laceration (which may be subtle) is not missed during the acute management of midfacial fractures (5).

Clinical Findings

A subtle notching of the lid medial to the punctum or mild displacement of the punctum laterally may be the clues to a lacerated canaliculus (Fig. 2A). Gentle manipulation with a cotton tip applicator or evaluation with a biomicroscope can aid in the diagnosis (Fig. 2B). Gentle probing or irrigation can be helpful in confirming canalicular injury. Obvious displacement of the punctum makes the need for surgical repair clear.

Treatment

Repair of a lacerated canaliculus requires silicone intubation as the initial step. A modest injury with laceration of one canaliculus can be managed with a monocanicular stent such as a Mini-Monoka (Fig. 3). Bicanalicular injury, or injuries that are extensive are better repaired utilizing bicanalicular intubation. Several systems are available. Popular silicone intubation systems are the Guibor set and the Ritling tubes. A Mini-Monoka can be inserted in through the punctum and pulled through the wound to seat it. The proximal end is then cut to about 10 to 15 mm and inserted in the canaliculus. The medial canthal ligament can be approximated by two fine 6-0 polygalactate sutures placed adjacent to the canaliculus as the stent guides the cut end of the canaliculus together. For more complex injuries, the upper and lower canaliculi are intubated utilizing the systems with attached probes that allow the silicone to be brought from the nares. Following intubation of the system, the tubes are tied together with a single 6-0 silk placed in the lacrimal sac as described by Merbs et al. (6).

This procedure allows a precise tension to be established so there is no risk of erosion, and no possibility of dislodging of the tubes. The medial canthal ligaments are then reapproximated with the 6-0 vicryl sutures serving to align the canaliculi (Fig. 4).

The silicone stent is left in place for six months. It can easily be removed by cutting the loop at the medial canthus and pulling the tube with attached 6-0 silk knot through the punctum. If only one canaliculus was lacerated, it is recommended that the knot be brought through the uninjured canaliculus, since it is less likely to be stenotic.

Canalicular Obstruction

Canalicular, including common canalicular obstruction, can occur as the result of past trauma, infectious processes such as severe conjunctivitis, or as a complication of topical or systemic medications. Scarring as the result of unrecognized canalicular trauma can lead to complete

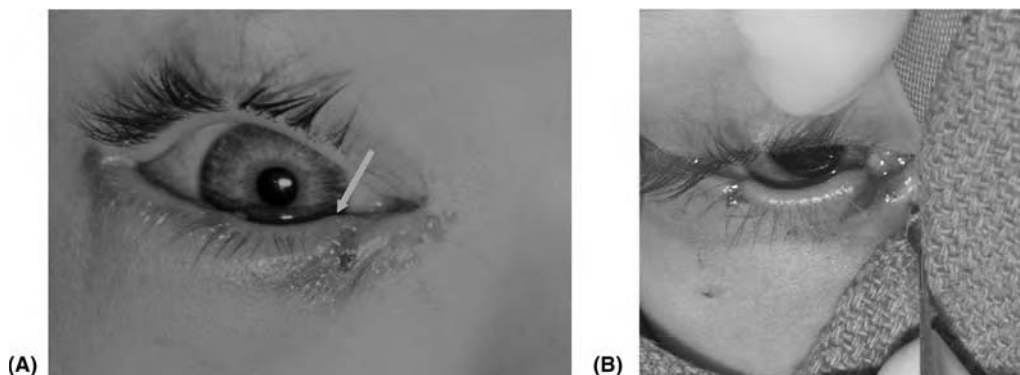


FIGURE 2 (A) Canalicular laceration, laterally displaced punctum (arrow). (B) Punctum retracted showing laceration.

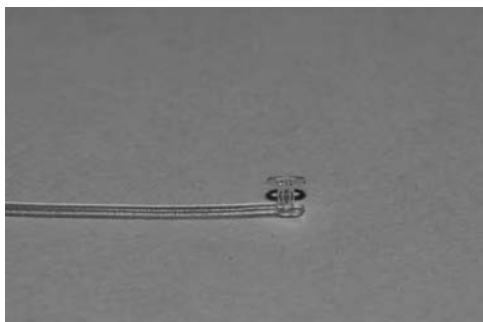


FIGURE 3 Mini-Monoka canalicular stent.

outflow obstruction. Effective transnasal wiring in the setting of midfacial fracture requires firm attachment of wire or suture to the medial canthal ligament. The canalicular system is immediately posterior to the medial canthal ligament and iatrogenic injury to the system can lead to irreparable obstruction. A lacrimal probe should be placed in the system at the time of placement of the medial canthal suture to confirm the protection of the canaliculi. Herpes simplex ocular infections and the topical medications prescribed for them have been implicated as causes of canalicular stenosis. Systemic 5-fluorouracil has long been known to be a cause of canalicular stenosis to the extent that surgery was needed (7).

More recently, docetaxel, used in the treatment of breast and prostate carcinoma has been linked to canalicular and nasolacrimal duct stenosis (8).

Treatment

Silicone Intubation

Localized canalicular obstructions as would occur with an old healed laceration can be resected and the system intubated. Broader stenosis, as would occur with infectious or inflammatory processes, can occasionally be resected and/or probed open. If the canalicular system cannot be readily probed to open it, silicone intubation is poorly effective and a bypass procedure is needed. While transcanalicular laser recanalization and mucosal tracts constructed from the



FIGURE 4 Silicone intubation of the canaliculi and medial canthal suture.

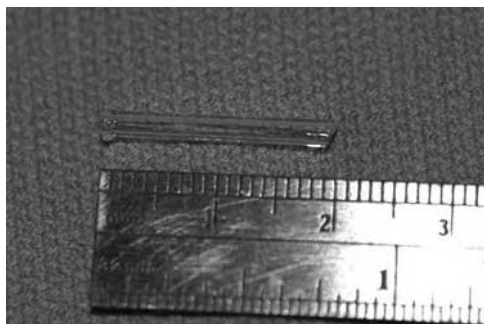


FIGURE 5 Jones conjunctivorhinostomy tube.

nose to the medial conjunctival cul de sac have been reported to afford some success, conjunctiv-orhinostomy (Jones) tube has remained the favored treatment for canalicular obstruction.

Conjunctivorhinostomy (Jones tube)

The Jones tube (Fig. 5) is a pyrex glass tube used to bypass a permanently obstructed canalicular system. Sekhar et al. (9) report successful relief of epiphora of up to 98.5% of eyes treated with Jones tubes, but to achieve that, adjustments, excision of overgrowth of tissue, flushings, and other manipulations were necessary. In their series of 58 patients (69 eyes), complications included tube displacement in 57.9%, tube obstruction in 27.5%, and infection of the lacrimal sac occurred in four of the 69 eyes. However, they concluded that the tubes could be made to work well when these problems were managed, and Jones tubes remain the best treatment for permanent canalicular obstruction. Rosen et al. caution that Jones tubes are not for everyone with epiphora from canalicular obstruction. They reported that in spite of 92.6% functioning Jones tubes in their study group of 121 patients, there was patient dissatisfaction in 13 patients and 36 patients reported having more complications than expected. Patients over 70 (10 of 46) and under 19 (one in four) had the highest rate of dissatisfaction. The authors recommended Jones tubes only in extremely symptomatic individuals in those age groups and care in explaining the tube's limitations to prevent unrealistic expectations (10).

An incision placed along the anterior lacrimal crest resulting in scar a barely perceptible scar. The inferior one-half of the caruncle is excised. Incision along the anterior lacrimal crest, dissection to the medial wall of the lacrimal sac fossa, and removal of the medial wall of the fossa with a sphenoid punch are carried out as is described below for DCR. The nasal mucosa is opened and a punctal dilator is then passed through from the area of the inferior portion of the caruncle into the nose. The passageway is further dilated and a probe with the Jones tube on it is passed through the opening into the nose. The tube is then pushed into place. A rigid endoscope is used to evaluate the position of the end of the tube in the nose to be sure it is not obstructed. A change in tube length may be needed to achieve an unobstructed fit with an adequate 1 to 3 mm of the tube within the nose. The lateral aspect of the tube is sutured to the adjacent tissue with a deep mattress 5-0 nylon that has been tied around the tube adjacent to the flange. The skin incision is then closed. Double flange tubes (Gladstone-Putterman) (11) and tubes coated in Medpor (Porex, Inc.) (12) are modifications of the original Jones tube designed to facilitate fixation and retention (Fig. 6).

Canaliculitis

Clinical Findings

Epiphora is usually the presenting symptom of canaliculitis. Unilateral conjunctivitis, which may be chronic or recurring, and which may center on the medial canthus, is a frequent finding. A follicular response is associated with a mucopurulent discharge. These processes may go on for months to years, correct diagnosis not made, and a variety of topical antibiotics or steroid medications used. Subsequently, the area of the canaliculus swells and becomes erythematous (Fig. 7). The inflammation at the medial aspect of the lid can be mistaken for a chalazion (13). The punctum may be swollen shut or pouting. In advanced canaliculitis, canalicular diverticuli can form. The diverticuli can become quite large, as large as the lacrimal sac itself, and

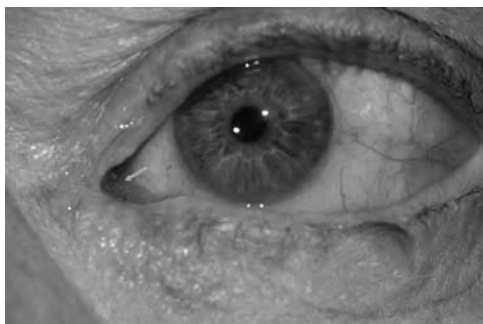


FIGURE 6 Properly placed Jones tube.

spontaneous fistula formation has been reported (2). Concretions can occasionally be expressed by pressing on each side of the canaliculus toward the punctum. The type of concretions depends on the infectious agent.

Throughout the course of the disease it may be possible to irrigate or probe the system. Firm concretions cause a gritty feeling as the probe is passed. The punctum may be blocked with the material filling the canaliculus. Dacryocystograms show an irregularity to the canalicular epithelium and may demonstrate diverticuli or filling defects caused by the concretions.

Epidemiology

Approximately 2% of patients with lacrimal disease present with canaliculitis (14). The average age is 54 years (range 14–96 years) (15). While one report suggests the inferior canaliculus is more frequently affected than the superior (14), the study was of a small number of patients and there is no good evidence of preferential site. Elliot reported nine cases: two upper, two both, and five lower. All were women ranging in age from 10 to 58 years (16).

Pathology

The cause of canaliculitis and whether the diverticuli that are observed with the disease are part of the cause, or as a result of the chronic infection, are not known. Nunery and Wilson suggest that there may be congenital diverticuli which provide nidus areas for the beginning of infection and present an anaerobic environment. They point out, however, that *Actinomyces* tends to cause suppurative tracts and it is possible, therefore, that the diverticuli are a result rather than a cause of the canaliculitis (15).

Nonsuppurative canalicular inflammation can occur secondary to periocular infections caused by *Herpes simplex*, *Herpes zoster*, or trachoma. Trachomatous canaliculitis results from the spread from the conjunctiva to the canaliculus. Granulomatous reaction occurs in the pericanalicular tissue and mucous membrane with resultant purulent discharge. Ultimately, however, cicatricial contraction leads to significant stricture of the canaliculus. Secondary infection then occurs (2).

Kalt (2) described a conjunctival inflammation which seemed to spread into the canaliculus and cause a follicular canaliculitis. While not part of the spectrum of primary suppurative



FIGURE 7 Canaliculitis.

canaliculitis, inflammation, and stenosis can obstruct the canaliculus secondary to pericanalicular infection. This differs from suppurative canaliculitis, which is characterized by primary canalicular infection with purulent discharge originating in the canaliculus and evident at the punctum.

Secondary canaliculitis can also occur as a result of spread of infection from either acute or chronic dacryocystitis (2). Retained foreign bodies have been reported as a cause of canaliculitis. Becker reported canaliculitis secondary to *Enterobacter* and *Klebsiella* species as a result of retained Veirs rod (17). Rootman et al. reported *Mycobacterium chelonae* canaliculitis after silicone intubation (18).

Microbiology

Actinomyces israelii is the most commonly identified cause of canaliculitis. Originally termed streptothrix, this pathogen was described by Israel in 1878 (19). *A. israelii* is an anaerobic gram-positive bacterium. It is normal flora in the human mouth.

Actinomycetes are bacteria but may be confused with fungi because they tend to be filamentous. They orient in radially arranged branching clumps. While the microscopic appearance may be that of fungi, they differ in that they lack nuclear membranes, have bacterial cell walls, undergo genetic recombination typical of bacteria and not fungi, and can be infected by virus particles, which is characteristic of bacteria and not fungi (20).

A. israelii causes suppurative sinus tracts and scarring. An exudate is produced which contains granules that have been termed "sulphur granules." These yellowish cheese-like granules have a gritty consistency, and when examined with Gram stain are shown to contain masses of gram-positive, branching, filamentous organisms.

A second anerobic organism implicated as a cause of canalicular infection, *Arachnia propionica*, was first discovered in a case of canaliculitis (21). Originally believed to be a new species in the genus *Actinomyces*, it was reclassified to *A. propionica* (22) and differs from *A. israelii* in that it produces propionic acid in broth and does not ferment arabinose, cellobiose, salicin, or xylose. It has different surface antigens and contains diaminopimelic acid in its cell wall (23). The gram stain appearance of *A. israelii* and *A. propionica* is the same; therefore cases of canaliculitis due to the latter organism may have been ascribed to *A. israelii* (22).

Pine and associates in 1961 (24) examined the normal flora of the human lacrimal system and did not find anerobic *Actinomycetes*; however, they did find the anerobe *Propionibacterium acnes*, suggesting that the lacrimal system contains an anerobic environment but that the *Actinomycetes* are not normally present. Another anerobic bacillus, *Fusobacterium nucleotum*, is a gram-negative organism, which has been reported to cause suppurative canaliculitis (25), and, while it is present in normal oral flora, it is only found in the canaliculi when there is active canaliculitis (24). The suggestion is that the most common cause of canaliculitis is infection with normal anerobic oral flora.

Of the multitude of bacteria and fungi that have been found to cause canaliculitis, some are associated with characteristic clinical findings which may suggest the nature of the organism. The diverticuli and concretions commonly seen with *A. israelii* infections can also occur as a result of fusobacterial infections (25). Rubbery concretions occur in the presence of *Candida* infections, while *Aspergillus niger* causes brown or black debris to accumulate (15). *Enterobacter cloacae*, a common intestinal organism also found in soil and water, produces a tenacious mucoid material within the canaliculus (26).

Other reported causes of suppurative canaliculitis include *Streptomyces somaliensis* (27), *rhinosporidium* (28), *nocardia asteroides* (29), *sporotrichum* (18), *cephalosporium* (28), and *Pityrosporum pachydermatis* (30).

Gram stains of the exudate and concretions should be done, and Giemsa stain may be helpful in identifying fungi. Anerobic and fungal cultures similarly may be helpful in some cases, while aerobic cultures are of no value for isolating the most common causes of canaliculitis.

Treatment

While laboratory identification of the causative organism may be helpful, the cornerstone of treatment is surgery. Topical and systemic therapy with antibiotics is ineffective unless there is surgical removal of concretions and debris. A probe is inserted in the canaliculus and incision

made through the adjacent conjunctiva into the dilated canaliculus. A small curette can be used to remove the debris. The incision need not be closed. Irrigation with antibiotic solution at the time of surgery and treatment with oral antibiotics seven to 10 days may be helpful. *A. Israelii* is resistant to neomycin, gentamicin, and tobramycin. However, it is sensitive to penicillin, erythromycin, tetracycline, and bacitracin (15). Prompt resolution is usually the case and recurrences are rare. Treatment solely with antibiotics or steroids without draining the canaliculus will not be successful. Pavilack and Frueh (31) reported that simple curettage through the punctum, without canaliculotomy, in 11 patients caused a resolution of the canaliculitis in all. Silicone intubation was needed in one patient and curettage was needed more than once in some cases. Silicone intubation in addition to canaliculotomy may offer additional benefit.

LACRIMAL SAC AND NASOLACRIMAL DUCT

Dacryocystitis

Clinical Presentation

Acute Dacryocystitis

Acute dacryocystitis presents with a painful inflammatory response in the medial canthal area (Fig. 8). Pain may radiate into the frontal area or down into the teeth. Swelling may be initially diffuse, localizing at a point under the medial canthal ligament as the process progresses. Erythema of the overlying skin and that of the lower lid and cheek is common. A diffuse swelling may obscure the elevation in the area of the lacrimal sac. Point tenderness just below the medial canthal ligament is a constant finding. Frequently it is not possible to express purulent material from the puncta for swelling closes off the common canaliculus. There may be a progression to spontaneous rupture of the abscess within days. Following perforation through the skin, temporary quieting of the infection occurs, with recurrence of pressure, pain, and inflammation sometime after the skin closes. Occasionally, a fistula forms allowing chronic drainage.

Chronic Dacryocystitis

Chronic dacryocystitis is associated with epiphora and often conjunctivitis. There is swelling and occasionally (but not necessarily) erythema inferior to the medial canthal ligament (Fig. 9). Episodes wax and wane. It may be possible to express mucopurulent material from the puncta by exerting pressure on the lacrimal sac, though kinking of the common canaliculus often prevents reflux through the puncta. Occasionally, a chronic lacrimal mucocele can become infected and form a distended pyocele. Progression to the clinical picture of acute dacryocystitis can occur.

Epidemiology

Dacryocystitis is predominantly a disease of middle-aged adults. It is rare in childhood and adolescence (2), and when it occurs in the pediatric age group (excluding neonatal dacryocystitis) suspicion should be heightened to the presence of an underlying disorder, particularly if the process is bilateral. Exanthematous diseases, which contribute to chronic inflammation of the lacrimal sac in childhood and adolescence, can lead to chronic dacryocystitis. One report by Mukherjee et al. (32) presented a series which included 28 cases of acquired (noncongenital) dacryocystitis in patients up to age 15. Fifty percent had had chicken pox while another nine of



FIGURE 8 Acute dacryocystitis.

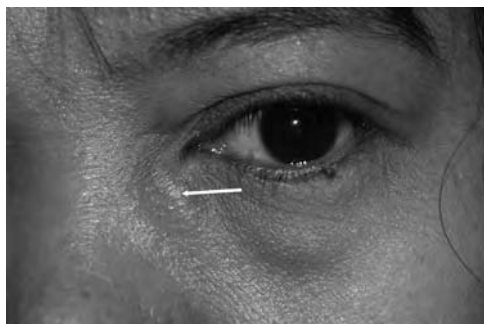


FIGURE 9 Lacrimal mucocele (*arrow indicates distended sac*).

the 28 had had smallpox. The remaining five cases were felt to be idiopathic. Rarer disorders such as sinus histiocytosis (33) and mucocutaneous lymph node syndrome (Kawasaki's disease) (34) have been reported as predisposing factors in the development of dacryocystitis in children. Neonatal dacryocystitis affects the sexes equally, but in adults, females are affected in a four to one ratio to males (35). Meller et al. (2) suggested the narrower lumen of the bony nasolacrimal canal in females was a contributing factor. Heininen (2) implicated a higher narrower nose on average in females as compared to males, and hormonal influences have been thought to play a part (36). The disease is rarer in those of African descent than in Caucasians possibly due to differences in the nasolacrimal canal, which is shorter, wider, less sinuous, and has a larger ostium. Reports from the early 20th century suggest Caucasians are more likely affected in tropical than temperate countries (2). While dacryocystitis is usually sporadic, familial, and autosomal-dominant inheritance patterns have been reported (35).

Predisposing Factors

While dacryocystitis can be secondary to pericycstic inflammation and infections, gross infections in the nose and sinuses, or can be related to conjunctival diseases, in a majority of cases primary dacryocystitis is secondary to nasolacrimal duct obstruction. The cause of the obstruction may be endogenous, exogenous, or of an unknown etiology. While inflammation in with secondary constriction of the nasolacrimal duct is a frequent cause for obstruction, the cause for the inflammation is not clear.

Radiological Evaluation

Effective management of an obstructed lacrimal outflow system depends on a thorough understanding of the etiological factors. History and clinical evaluation often can provide adequate guidance and further diagnostic maneuvers are unnecessary. However, computed tomography (CT) and magnetic resonance imaging (MRI) evaluation can be helpful in providing understanding of the pathologic processes. In a study by Frances et al. (37), in 14 of 107 patients presenting with epiphora, preoperative CT of the lacrimal drainage system resulted in the alteration in patient management. Findings included two tumors extrinsic to the lacrimal sac, ethmoiditis, gross nasal polyposis, and fungal sinusitis. The gold standard for lacrimal duct radiologic evaluation remains the dacryocystogram, now performed utilizing CT, but can be done using conventional radiography. A water-based (e.g., iohexol) or oil-based (e.g., lipiodol) contrast material is irrigated into the lacrimal system through a canaliculus. This test is particularly helpful in evaluating intrinsic sac processes and the possibilities for explaining the epiphora as being on the basis of sac or nasolacrimal duct stenosis. The physiologic functioning of the entire outflow system is more poorly evaluated because the technique bypasses the puncta and canaliculi and involves a nonphysiologic syringing of the contrast material through the system. CT scanning of the lacrimal outflow system after instillation of iohexol in the conjunctival cul de sac is a procedure that addresses these shortcomings (38). The effectiveness of outflow drainage as well as the possibility of intrasac or extrasac pathology is evaluated. MRI following the instillation of gadolinium drops may give useful information in patients with complex epiphora problems, but the expense and complexity of the study at this time rarely justify its use (39).

Epiphora or dacryocystitis following trauma presents a situation in which CT imaging is particularly useful. Radiographic findings pertinent to surgical management are frequently present including alterations in bony anatomy, fixation materials, or implants adjacent to the sac, sinusitis, anterior ethmoid air cells, and abnormalities of the septum or turbinates (40). Dacryocystography furthers the usefulness of a CT scan by delineating the contours of the lacrimal sac and its relation to adjacent structures (41).

Causes of Obstruction

Chronic Inflammation

Clinical pathologic study of the lacrimal sac reported by Mauriello et al. (42) demonstrated the effects of chronic inflammation in the lacrimal sac. Of 44 patients who had DCRs 18 patients had had 1 to 20 episodes of dacryocystitis. Chronic inflammatory changes were noted in patients who had been tearing only and in those who had had previous attacks of dacryocystitis. A chronic low-grade inflammation leads to fibrosis of the lacrimal sac and the common internal punctum. The lacrimal sac pseudostratified, ciliated, columnar epithelium undergoes changes of squamous metaplasia, and hyperplasia with loss of goblet cells and ulceration. Most patients had evidence of chronic subepithelial inflammatory cell infiltrates, which consisted predominately of lymphocytes and plasma cells. Subepithelial fibrosis was present in 34 of the 37 cases. A similar process was reported by Linberg to occur in the nasolacrimal duct. Chronic inflammation causes secondary fibrosis and that in turn causes gradual narrowing of the nasolacrimal duct until complete obstruction occurs (43).

When the lacrimal passages are functioning normally, the flow of bacteriostatic tears and the resistance of the mucosa itself to infection provide protection. Even severe bacterial infections of the conjunctiva rarely extend down into the sac. Therefore, stasis within the sac is a prerequisite for the development of infection. The narrow, bony canal provides confines with the result that any swelling will lead to blockage. A partially stenosed canal is more sensitive to the effects of inflammation, and the numerous folds and valves in the mucous membrane of the sac combine with a submucosa which is vascular leading, with little insult, to enough swelling to cause a fluid back-up.

Congenital Variations

Congenital variations in the shape and size of the osseous canal impact on the chance of developing dacryocystitis and may explain some familial transmission of the disease. Heinonin in 1920 and Seidenari in 1947 described cases of dacryocystitis associated with narrowing of the osseous canal occurring in patients with a flat nose and narrow face. Whitnall related a narrow osseous canal to an underdeveloped lacrimal bone (2).

Associated Nasal or Sinus disease

Nasal disease can be significant in the etiology of obstruction. Mechanical obstruction can result from enlargement or flattening of the inferior turbinate, which can nearly obliterate the anterior part of the inferior meatus and may cause a chronic local rhinitis. Septal deviation can compress the inferior turbinate against the lateral nasal wall. Congestive, inflammatory, and hypertrophic conditions of the nasal mucosa can cause obstruction. Atrophic conditions of the nose are also associated with dacryocystitis. Heilmayer in 1899 found 136 cases of atrophic rhinitis from 352 cases of dacryocystitis (2). While there is some argument as to the part sinus disease plays in the etiology of dacryocystitis, there are many reports that suggest a relationship. Kuhnt, in 1914, reported 68% cases of dacryocystitis having sinus disease, and an additional 23% with probable sinus disease (2). While it is suggested that infections spread by venous or lymphatic pathways to the lacrimal area and in some cases by direct continuity, lacrimal outflow obstruction from nasal mucosal disease related to sinus inflammation is a more likely mechanism (2).

Nasolacrimal duct obstruction has been associated with nasal allergy (44), viral or bacterial pharyngitis and rhinitis can produce sufficient nasal mucosal edema, lymphoid hyperplasia, and exudate to cause obstruction of the nasolacrimal duct and dacryocystitis (45).

Extrinsic Neoplasia

External compression of the nasolacrimal duct or of the lacrimal sac can cause secondary dacryocystitis. Benign or malignant neoplasia of the adjacent paranasal sinuses or of the nasal cavity can impinge on the outflow channel. Dacryocystitis may be the presenting sign of a paranasal sinus neoplasm (46). Secondary involvement of the lacrimal drainage system by lesions affecting adjacent structures is more common than primary neoplasia of the system (47). Invasion or compression has been related to adenoid cystic carcinoma (48), sebaceous gland carcinoma (49), and osteoma (50,51). Bartley reports nasolacrimal obstruction secondary to adenoid cystic carcinoma, basal cell carcinoma, asthesioneuroblastoma, intraosseous cavernous hemangioma, leukemia, lymphoma, mucoepidermoid carcinoma, squamous cell carcinoma, and orbital lesions such as rhabdomyosarcoma (47). Tumors that arise within the maxillary antrum can occlude the nasolacrimal duct and squamous cell carcinoma is the most common (52–55). Sinus histiocytosis can cause lacrimal obstruction by intrinsic involvement of the lacrimal drainage system (56), or by involvement of nasal mucosa adjacent to the nasolacrimal duct ostium (33,57,58).

Tumors of the Lacrimal Sac

Primary neoplasia of the lacrimal sac are less common as a cause of dacryocystitis than are those involving the system secondarily. Flanagan and Stokes (59) emphasized that a blood stained discharge from the puncta is strongly suggestive of neoplastic involvement of the sac. Most common lesions are those of epithelial origin, including papillomas and squamous cell carcinomas (47,59–66). Radnót et al. reported in a review of tumors of the lacrimal sac that 25% were pseudotumors or inflammatory granulomas (67). Pyogenic granulomas of the sac are reported associated with chronic dacryocystitis and in one study represented 53% of the 15 lacrimal sac tumors found over a period of 10 years (68). Polyps of the lacrimal sac present a chronic inflammation and suppuration and occasionally pus emits from the puncta (59). Madreperla et al. linked human papillomavirus infection of the lacrimal sac to benign and malignant primary epithelial tumors in the sac (69). Other tumors intrinsic to the sac include hemangiopericytoma (70) and, rarely, adenoid cystic carcinoma (71).

Re-establishment of lacrimal drainage following tumor excision often requires the placement of a conjunctivorhinostomy tube. In the case of the removal of a malignant neoplasm, an adequate tumor free period is recommended before the placement of the tube.

Trauma

Types of Injuries

Lacerations and avulsions can occur at any point from the lacrimal puncta to the opening at Hasner's valve in the nose. Similarly, contusions with secondary scarring can occur at any point along the drainage system. Fracture deformity in the medial canthus causes disruption in the common canalicular area and superior aspect of the sac. In the absence of direct laceration, the sac is usually intact at this point. Fractures inferior to the medial canthus can cause crush and shear/dislocation injuries to the lower portion of the lacrimal sac and nasolacrimal duct. The system may remain patent if realigned, or may be hopelessly contused or lacerated. Lacerations, edema, or hematoma within the nose can cause obstruction at Hasner's valve.

Iatrogenic Injury Nasolacrimal duct obstruction following elective surgery can be considered due to iatrogenic trauma to the nasolacrimal outflow system or postoperative cicatricial change that results in lacrimal outflow compromise. Iatrogenic trauma to the nasolacrimal duct with secondary dacryocystitis can occur following nasal, sinus, or orbital surgery (72–75). Orbital floor fracture repair can result in secondary lacrimal obstruction as a result of impingement of the implanted alloplastic plate on the lacrimal system. The obstruction of the lacrimal system can occur many years after the repair (76). Craniofacial procedures can also result in lacrimal obstruction (47).



FIGURE 10 (A) Naso-orbital-ethmoidal fracture. Swelling and shifted bone fragments make probing of the lacrimal system unwise. (B) Computed tomography of patient shown in (A). Shifted fragments displace and compress the nasolacrimal duct and sac (arrow).

Midface Trauma Midfacial trauma, particularly those associated with fractures of the nose, maxilla, and medial orbit can easily cause partial or complete obstruction of the nasolacrimal duct as a result of the shifting of bone fragments (77) (Fig. 10A and B). However, while it would appear that significant trauma to the midface would cause lacrimal damage and obstruction, post-traumatic nasolacrimal obstruction is far from inevitable. Stranc (78) reported that of 25 patients who had NOE repair, six had epiphora postoperatively.

Gruss et al. (79) reported that 17.4% of patients required late DCR following the repair of an NOE. They felt eyelid malposition was more frequently the cause of epiphora than lacrimal obstruction. Of 57 patients requiring DCR reported by Jones, 14 had had trauma (80).

In the setting of significant midfacial trauma it would seem that acute management of perceived nasolacrimal or common canalicular obstruction with silicone intubation would provide more reliable long-term patency. However, this has not been proven. In fact, the difficulties arising from the attempt to maintain patency of the system can lead to more complications than if the lacrimal system is left alone. The reason for this lies with two basic problems. First, it is impossible to determine at the time of acute correction of significant midfacial trauma if the lacrimal system is blocked as a result of shifted fragments, hemorrhage, edema, contusion, or internal laceration. Second, manipulation of the lacrimal system with probes or an attempt to intubate it has a high chance of causing further damage. Passageways that are normally tenuous and narrow are swollen and distorted as a result of the trauma. Probes easily pass through the walls of the system forming false passages and adding to the damage.

It may be difficult or impossible in the presence of significant contusion, hemorrhage, and comminuted fracture dislocation of surrounding bones to determine the correct passage for a probe. Induration in the medial canthal area makes the atraumatic passage of probes through the puncta nearly impossible in some cases. Punctal and canalicular tears may be difficult to avoid. When the bone fragment attached to the medial canthal ligament displaces laterally there is distortion in the area of the common canaliculus. A probe has significant chance of being misdirected through the wall in the area of the common canaliculus. Fracture dislocations in the lacrimal bone and anterior lacrimal crest area increase the risk of a false passage through the wall of the lacrimal sac or nasolacrimal duct. Harris and Fuerste (81), on the basis of their experience with seven cases (11 lacrimal systems), recommended intubation of the lacrimal system with silicone if radiographic evidence of damage to the lacrimal sac fossa or lacrimal canal was present, and the sac or nasolacrimal duct could be seen at the time of surgery to be disrupted. In this series, two systems were excluded from follow-up analysis, and the remaining nine all were functioning and the patients were free from epiphora following the removal of the stents. However, the authors felt the silicone passed through all aspects of the lacrimal system in only 2 of 11 instances. In the other cases the tubes bypassed some portion of the nasolacrimal duct. While it is hard to argue with their success, it is difficult to determine at the time of surgery in which cases the nasolacrimal ducts are irreparably damaged and should be bypassed. Management of presumed injury to the lacrimal system must be tempered by two considerations. First, it may not be possible at the time of acute fracture repair to determine if the lacrimal system is injured to the point that postoperative

obstruction would cause significant epiphora. Second, the distortion of the lacrimal anatomy increases the risk of iatrogenic injury resulting from attempts to establish or maintain patency of the system. While canalicular avulsion or laceration should be repaired acutely, it still can be argued that it is best to defer surgery on the lacrimal sac or nasolacrimal duct until the late postoperative period.

Transnasal canthopexy can add additional risks to the canalicular system. The medial canthal ligament lies just anterior to the lacrimal canaliculi. Transnasal canthopexy with suture or wire fixation through the medial canthal ligament is necessary in many cases of NOE fractures. Suture ligation obstruction of the canaliculi can occur if the suture is not carefully placed to avoid the canaliculi. A probe placed in the canalicular system can help delimit these structures and prevent inadvertent suture constriction.

Failures in Management

Late effects on the lacrimal system result from secondary cicatricial changes that may be unavoidable. However, failure to align bone fragments and restore anatomy in the area of any components of the lacrimal system can lead to chronic obstruction as a result of misalignment of the relatively narrow lacrimal passageways. Furthermore, failure to stabilize bone fragments with appropriate internal fixation can result in the collapse of the bones of the midface onto the lacrimal sac and nasolacrimal duct with secondary obstruction (82). Closed reduction with external splint fixation results in external compression of the lacrimal sac/nasolacrimal duct area resulting in an increased likelihood for chronic obstruction (81). Fifty percent of the cases reported by Stranc had closed reduction and external fixation plates. Five of the six patients who had postoperative epiphora were in the closed-reduction group (78). Currently advocated principles of NOE fracture management including open reduction and internal fixation must be adhered to in order to minimize the chances of lacrimal obstruction.

The lacrimal sac is surrounded by the periosteum extending along the inferior one-third of the lacrimal sac and down around the nasolacrimal duct. Superiorly, in the area of the medial canthal ligament attachment, periosteum reinforces the medial wall at the sac. This protection helps prevent damage to the sac at the time of the injury and also during dissection. However, overaggressive dissection of the sac in order to free the medial canthus, or for anatomical positioning, can cause damage to the sac and care should be taken to protect this structure during inferior-medial or anterior-medial orbital dissection. Similarly, damage to the canalicular system during dissection can occur. This usually does not occur during the obtaining of bone exposure but rather at the time the medial canthal ligament is being isolated for attachment when transnasal wiring is being done.

Manipulation within the nose can damage or destroy the nasolacrimal duct opening just inferior to the inferior turbinate. The insertion of instruments along the floor of the nose during the management of the fractures should always be done keeping the anatomy of the lacrimal system in mind.

Summary

It can be extremely difficult to determine the extent of injury to the lacrimal system when there have been extensive midfacial fractures. Some aspects of the lacrimal drainage apparatus may be patent at the time of initial repair and subsequently may close as a result of scarring of contused areas. On the other hand, swelling may cause the system to be closed at the time of initial repair only to have it open later. Therefore, while it could be considered helpful to intubate the contused passages to prevent later obstruction, the tissues are so distorted in many cases that manipulation of the system acutely is discouraged for it has as much chance of hurting as helping. The delicate canalicular system can be injured by attempts to intubate a nasolacrimal duct that may not even need it. Report of success with acute intubation is based too few cases to draw firm conclusions.

Considering the significant risk of furthering injury to the lacrimal system with attempts to keep it patent, the acute management of the lacrimal system at the time of repair of fractures involving the central midface can be summarized as follows:

Lacerations and avulsions of the canalicular system should be treated acutely with silicone intubation. This has to be done extremely carefully to prevent false passages elsewhere in

the system as has been discussed. These lacerations are the only indications for direct surgery on the lacrimal system during the acute management of midfacial fractures.

Nasolacrimal duct obstruction or inferior lacrimal sac obstruction can be treated readily at a later date by DCR. Acute DCR is not advisable. Not only can it interfere with other aspects of the repair, but as has been mentioned, it is difficult to determine whether or not it is indicated in the acute setting.

Systemic Disease

Systemic infections have been associated with nasolacrimal duct obstruction and dacryocystitis. Influenzas, scarlet fever, diphtheria, syphilis, and chicken pox have been reported to cause dacryocystitis or have dacryocystitis associated (2). Sarcoid can involve the lacrimal sac directly and cause acute dacryocystitis (83). Dacryocystitis can be a complication of Wegener's granulomatosis, and DCR in these patients can be complicated by necrosis and fistulization at the wound. For those reasons, dacryocystectomy has been recommended by some for treatment of dacryocystitis in these patients (84). Acute dacryocystitis has been reported in association with nasopharyngeal hyperplasia secondary to infectious mononucleosis in a child (85).

Dacryoliths

Calculi of the lacrimal sac were reported as early as 1922 (86). In spite of this, the mechanism by which these masses form is still to be elucidated. A variety of substances have been identified in dacryoliths, including calcium, phosphates, ammonium, and cystine (87). Calcium, phosphates, and ammonium are found in the tears, but not in large concentrations. Maltzman and Favetta postulate that in nonmycotic dacryoliths, inflammatory plaques on the mucosal tissue provide a nidus for ion aggregation. They further suggest that protein structures must have broken down in the lacrimal system secondary to micro-organism action (87). Kaye-Wilson reported the analysis of a dacryolith showing coagulase-negative staphylococci, urate, phosphate, and fibrin (88). Urate is derived from the cell nuclear purine degradation suggesting that dacryolith formation occurred as the result of slow aggregation of cellular debris for an extended period. The fact that antikeratin antibodies have been found in a dacryolith supports this theory (89). Inflammation, with resultant fibrin aggregation, may be due to stagnant infection or irritation by the stone. Medications have been reported to play a part, and adrenochrome dacryoliths have been found (90).

Several authors have suggested that fungus plays a part in dacryolith formation (91–93). Similarly, there are many reports of dacryoliths in which no fungi were found (80,94,95). Special studies are frequently not used to evaluate dacryoliths, and this impacts on fungal detection. Clearly dacryoliths may or may not be associated with fungi, and the exact relationship is unknown.

The reported prevalence of dacryolithiasis in all patients having DCRs is approximately 14% (95). Patients with a dacryolith tend to be younger (average age 45) than most patients undergoing DCRs (average age 52) and tend to give a longer history (4.8 years) of intermittent epiphora and intermittent epiphora and pain (80,95). Hawes reported that in 43 patients who had DCRs for dacryocystitis, 15 had dacryoliths, and in 74 patients who had DCRs for epiphora without dacryocystitis only three had dacryoliths (95). Jones (80) found that in a review of 185 DCRs in patients over 50 years of age (123), three had dacryoliths. In patients under 50 years of age (57), 22 had dacryoliths. Of the 57 patients under age 50, 14 had obstruction due to trauma, four had had previous lacrimal surgery, three had internal common punctum obstruction with no tear sac involvement, and two had congenital closures. Of the remaining 34 patients, 22 had dacryoliths.

Microbiology of Dacryocystitis

Gram-positive cocci have generally been reported to be the most common infectious agents in acute dacryocystitis. In 1941, Traquair reported culture results on 251 out of 548 cases of dacryocystitis in adults (35). Pneumococci were most prevalent (24%) followed by staph albus (26%), streptococci (8%), and staph aureus (6%). Other organisms cultured, including diphtheroids

and coliform bacteria, made up 24% while there was no growth in 12%. Recent reports suggest that *Staphylococcus aureus* and coagulase-negative *Staphylococcus* play a much more prominent role in dacryocystitis (96–98). Codin et al. (98) reviewed 526 dacryocystorhinostomies done between 1984 and 1988. Two hundred thirty-six were done for dacryocystitis, and intra operative cultures were obtained on these patients. Positive cultures were obtained in 124 (52.5%). The report was a retrospective review, and the authors were unable to determine in some cases what preoperative empiric therapy of broad spectrum topical and systemic antibiotics was used. They noted that in addition to increasing the percentage of sterile cultures, it was possible that antibiotic treatment prior to culture could have affected the spectrum and relative prevalence of pathogens. These author's findings of *Staphylococcus* species as being most prevalent is supported by the reports of other authors (96,97,99–102). This is in contrast to several reports of *Streptococcus pneumoniae* as the most common organism (35,103–105). In Codin et al.'s report, *S. pneumoniae* account for only 2.3% of the overall isolates (98). Other recent reports suggest a prevalence of *S. pneumoniae* from 2% to 15% (96,106). Blicker and Buffam reported only 7% prevalence of *S. pneumoniae* but 47% *Staphylococcus epidermidis* and 27% *S. aureus* in a series of 30 dacryocystorhinostomies for dacryocystitis (107). It is notable that in this series, 32% of cases grew two or more organisms. Bale (106) and Coden et al. (98) reported the occurrence of mixed cultures in 4% and 29%, respectively.

Codin et al. reported 27% of all isolates as gram-negative organisms with *Pseudomonas aeruginosa* representing 31.9% (98). In contrast, Huber-Spitzy et al. and associates reported 11.7% *Escherichia coli* with *Pseudomonas* being second most common gram-negative cultured 5.5% of the time (96). Cahill and Burns (97). reported that in 12 cases of acute dacryocystitis gram-negative rods were present in seven patients. The remaining five patients were all infected with *S. aureus*. Of the seven gram-negative rods, two were *P. aeruginosa*, one was *Proteus mirabilis*, one was *Enterobacter cloacae*, and one was *Haemophilus influenzae*. Two could not be classified.

Anerobic bacteria have rarely been reported as a cause of dacryocystitis. *A. israelii* is frequently associated with canaliculitis but only a few cases have been reported as a cause of dacryocystitis. When dacryocystitis occurs as the result of *A. israelii*, the course is characterized by periods of quiescence interspersed with acute fistulizing exacerbations (108). Obstruction of the lacrimal system combined with further depletion of oxygen in the normally relatively anaerobic lacrimal passages by growth with aerobic bacteria, the presence of foreign bodies, and surgical manipulation have been implicated as predisposing factors for anaerobic growth. While reports of anaerobic involvement may be limited by the fact that careful anaerobic cultures may not be frequently done, Codin et al. found 7% in their series culture positive for anaerobic bacteria with the majority (66.7%) *Propionibacterium acnes* (98).

Fungal organisms have on occasion been implicated as a cause of dacryocystitis. For the most part, single case reports are found in the literature and the role of fungal organisms and lacrimal sac infections remains unknown. *Candida albicans* is the most commonly identified organism (109–111). *Candida parapsilosis*, *Candida krusei*, *Candida parakrusei*, *Aspergillus*, *Sporotrichosis*, *Tricophytosis*, and *Pityrosporum orbiculare* have been reported to cause dacryocystitis (112). Other fungi reported to cause dacryocystitis are Blastomycosis (113), Chromoblastomycosis (103), Rhinosporidiosis (2), Cryptococcus (2), Cephalosporiosis (2), and Actinomyces organisms (2). Fungus infection has been associated with dacryoliths (109), but, as has been noted, it is not clear whether the dacryoliths result from the fungal infection or whether or the fungi develop secondary to the dacryolith. Broad-spectrum antibiotics are frequently used empirically in treatment of dacryocystitis and this may have some impact on the prevalence of fungal organisms. The techniques used to determine the presence of fungi undoubtedly also impact on reported prevalence of these organisms. Berlin and coworkers found dacryoliths in 11 out of 70 consecutive dacryocystorhinostomies done for dacryocystitis or dacryostenosis (114). Only two of the stones had been cultured for anaerobes and fungi. One patient's stone grew the aerobes, *Pseudomonas*, and *S. pneumoniae*. Anaerobes, including *Bacteroides* and *Fusarium* species, were also found. The second stone grew fungi only including Cladosporium and Alternaria species. Six of 10 stones studied histologically demonstrated with special stains fungal elements. This contrasts with the report by Jones (80) and that of Smith et al. (115) in which no infectious agents were found in the stones.

A variety of unusual organisms round out the list of reported causative agents in dacryocystitis including *Trachoma* (116), *Treponema pallidum* (103), *Mycobacterium tuberculosis* (103), *Mycobacterium fortuitum* (117). Papilloma virus infection of the lacrimal sac has been linked to primary epithelial tumors in the sac and dacryocystitis (69).

Complications

While dacryocystitis rarely is associated with secondary complications, when complications occur they can be significant. Endophthalmitis following suture removal for penetrating keratoplasty has been reported as being secondary to dacryocystitis (118). Purgason and Hornblass reported one unfortunate patient who developed *Streptococcus viridans* endophthalmitis following cataract extraction (111). This organism was isolated from the punctum on that side. A second patient presented with a corneal ulcer that cultured positive for *C. albicans* and this organism was cultured from both lacrimal systems. Orbital cellulites (119) and recurrent facial cellulitis with fistula formation after midfacial trauma (120) have been reported secondary to dacryocystitis.

Treatment

Purulent material which can be expressed from the puncta should be sent for gram stain, and culture and sensitivity testing. Broad-spectrum antibiotics with good *Staphylococcus* effectiveness can be instituted until culture results are back. Huber-Spitz et al. (96) reported sensitivities found on 74 positive cultures for *Staphylococcus* (25 *S. aureus*, 49 Coagulase negative *Staphylococcus*). Norfloxacin was most effective for both *S. aureus* and coagulase negative *Staphylococcus* (96% and 95.9% sensitive, respectively). Tobramycin, neomycin, and bacitracin were moderately effective against both organisms (80–84% sensitive) and gentamicin, while effective for coagulase negative staph in 80%, was only effective for 64% of *S. aureus* isolates. Sulfonamides were poorly effective. Moderate to severe cases of acute dacryocystitis may require decompression of the sac by incision and drainage. Acute dacryocystitis treated with even the appropriate antibiotics may progress to spontaneous perforation for penetration of antibiotic agent into the sac is poor. Incision and drainage is a temporizing measure, the effectiveness of which may be increased by irrigation of the sac with antibiotic solution and filling the cavity with antibiotic ointment (97). DCR is the definitive treatment and can be done during the acute stages of the disorder. However, surgery at the time of acute dacryocystitis can be made considerably more difficult by the attendant hyperemia and induration, which make bleeding a problem and exposure difficult.

Incision and Drainage

A fluctuant dacryocystitis can be drained through the skin by a small incision at the level of the anterior lacrimal crest. Irrigation of the sac/abscess cavity with saline and/or a broad-spectrum antibiotic will allow in most cases a rapid quieting of the process. Elective DCR can then be planned at a time when the induration has subsided.

Nasolacrimal Duct Dilatation

There has been some enthusiasm in the past decade for the dilatation of nasolacrimal ducts that are stenotic with resultant epiphora, but not completely closed. A balloon catheter system has been devised as a means for that dilatation. The device has also been used for the treatment of failed DCR's. Becker and Berry (121) reported the resolution of symptoms in three out of four patients with failed DCR's who had balloon dilatation of the osteum. Kumar reported clinical improvement in 89% of a group of 31 patients who had the procedure instead of DCR for epiphora (122). Long-term results with one treatment are reported in one study to be 70% (123) which, though less than the success reported for DCR in this setting of 94% (124) still make this simple procedure an alternative to DCR to be considered in cases of incomplete obstruction.

A LacriCATH (Atrion Medical Products Inc., Allen, Texas) balloon is inserted through the superior canaliculus into the nasolacrimal duct, the position of which is estimated by a mark on

the shaft of the catheter. The balloon is then inflated to nine atmospheres (indicated on the attached gauge) for 90 seconds and then deflated. Repeat inflation to the same pressure is then done for 60 seconds. The catheter is withdrawn to a second mark and reinflated twice in a similar fashion ensuring complete dilatation of the duct. After deflation and removal of the catheter the system can be intubated with silicone and the tubes secured as has been described by Merbs et al. (6).

Dacryocystorhinostomy

The original procedure described by Toti consisted of resecting lacrimal sac mucosa, lacrimal sac fossa bone, and the nasal mucosa through a skin incision. In the early 20th century, Dupuy-Dutemps and Bourguet modified the procedure to include mucosal flaps to create a fistula into the nose. An incision along the side of the nose medial to the medial canthus with dissection of the periosteum and attached medial canthal ligament is used. Originally the suturing of anterior and posterior mucosal flaps was favored. Most lacrimal surgeons favor the suturing of an anterior flap of the wall of the lacrimal sac to an anteriorly based nasal mucosal flap at this time. Success rates generally are on the order of 90%. Modifications in an effort to push the success rate closer to 100% and decrease complications have included the introduction of various stents, changes in incision position, and the use of antifibrotic agents.

Shortly before the report by Toti, Caldwell proposed an endonasal DCR. He used an electric burr to create a middle meatal osteotomy in to the area of blockage as marked by a metal probe placed through the lacrimal system to the point of the blockage. The procedure was modified by West who, in 1914, described the removal of lacrimal bone and portion of the superior maxilla to make a window into the lacrimal duct (125). However, endonasal DCR gained little popularity until the 1970s and 1980s at which time endoscopic procedures were suggested as a reasonable option. In 1989, McDonough and Meiring (126) reported a clinical study of the procedure using endoscopes with fiberoptic delivery systems. The subsequent development of effective laser systems introduced another therapeutic dimension. Surgeons attacked the obstructed nasolacrimal duct from above with endolaser recanalization, and from below with laser-assisted endonasal DCR. These procedures touted the advantages of no scar, decreased pain, and no bruising with rapid recovery.

Endoscopic DCR

Endonasal laser DCR requires the use of expensive equipment and the occasional need to resort to more standard burrs or rongeurs to remove thick bone. The visualization and management of neoplasia that may extend into the orbit can be more difficult. There is a significant technical challenge to the surgeon performing endonasal DCR on a patient with midfacial trauma. Endonasal DCR, whether assisted by laser or not, requires multiple postoperative visits with manipulations of the endonasal osteum including irrigations and debridings (127). These visits can be inconvenient and unpleasant for the patient and are not necessary for patients who have had external DCRs. Endocanalicular laser-assisted DCR utilizing the Nd:YAG has been reported by Pearlman (128) to provide a success rate of 91%. In another report, Leib and Fay reported an 84% success rate (129). Endocanalicular surgery has been promoted as allowing the direction of the laser energy away from the eye, the use of local anesthesia, and short operation and convalescence time (130). Historically large osteums have been felt to provide improved success over small openings in spite of the fact that it has been shown that there is a shrinkage of osteum size to only 2 to 3 mm (131,132). It remains to be seen if the smaller openings produced by such procedures as endocanalicular laser intervention will stand the test of time. Certainly, another potential drawback of endocanalicular surgery is the limitation of the surgeon's ability to manage dacryoliths or other pathology.

External DCR

External DCR allows a more effective management of dacryoliths and neoplasia. While there are reports of endonasal procedures approaching the effectiveness of the external procedure, it is generally felt the best success rate for the management of nasolacrimal obstruction is afforded by an external approach. The arguments for endonasal DCR have been directed at the problems associated with the popular "standard" external DCR. The popular incision for DCR

has for more than 80 years been one placed along the side of the nose medial to the medial canthal ligament. A skin scar, possibly associated with webbing and a change in shape of the medial canthus, is frequently cited as reasons for the use of an endonasal approach. Displacement or rounding of the medial canthal angle is also possible complications of this approach. These complications are frequently cited as reasons for the use of an endoscopic approach. By making the incision along the anterior lacrimal crest as described by Iliff in 1954, those problems are eliminated (133). The incision falls imperceptibly in the area just below the inferior tarsal crease. The operative time with the use of Iliff's simplified DCR can be reduced to less than ½ hour. The success rate is comparable to that when the more difficult and time consuming suturing of flaps is done.

The Simplified External DCR

A procedure based on the "simplified DCR" of Iliff (133) provides equal success to the operation derived from the classic description of Dupuys-Dutemps (1) that is still favored by many lacrimal surgeons. Excellent exposure can be gained through a 1.5 cm. Incision along the anterior lacrimal crest. The incision begins just inferior to the medial canthal ligament. A bold incision down through the periosteum with one pass of the scalpel provides the least trauma to the tissues and excellent healing. A Freer periosteal elevator is used to reflect the periosteum and sac away from the medial wall of the lacrimal sac fossa (Fig. 11). The end of the Freer can be used to depress the anterior edge of the lamina papyracea at the suture line where it joins the lacrimal bone. A 1 mm Kerrison sphenoid punch then works well to remove the medial wall of the lacrimal sac fossa (Fig. 12). A radio frequency dissector is useful to open the lacrimal sac (Fig. 13). Placing a probe in the sac can facilitate identifying the position of the sac lumen and can guide the depth of the incision that is placed along the medial wall of the sac. Superior and inferior anterior cuts to form a U-shaped flap can be helpful in some cases, but is not necessary in all. A corresponding incision is made in the nasal mucosa. In most cases, a U-shaped incision is made in the nasal mucosa to create an anteriorly hinged flap.

The system is then intubated with silicone and the tubes are tied together in the lacrimal sac with a single 6-0 black silk (Fig. 14A and B). The loop is tested at the puncta to be sure there is no tension on the puncta and at the same time the loop cannot be pulled out enough to touch the cornea with the eye in primary position. A 12 fr red-rubber catheter is then threaded over the silicone into the sac where it is sutured in place with a 4-0 mild chromic mattress suture (Figs. 15 and 16). It is important that the catheter is in the lumen of the sac and does not roll the walls of the sac into its lumen. A mild traction on the catheter pulls the wall of the sac down to the osteum and into contact with the nasal mucosa. The inferior end of the tube is cut in the nose and sutured to the nose internally with a 5-0 nylon. The skin is closed with a fine suture, such as 8-0 nylon (Fig. 17).

Postoperative care includes systemic antibiotics for a week and topical antibiotic steroid drops such as tobramycin/dexamethasone qid. A similar ointment is applied to the stitches,

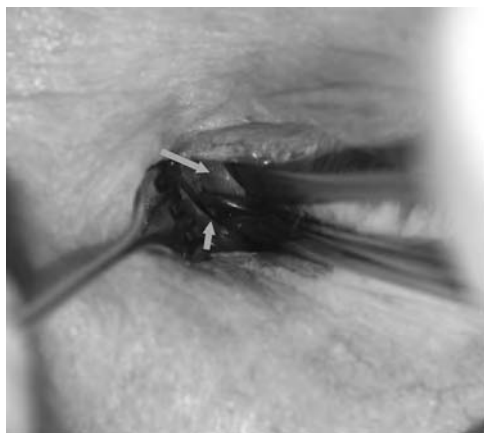


FIGURE 11 Sac reflected away from fossa (*long arrow indicates sac wall; short arrow indicates the anterior lacrimal crest*).



FIGURE 12 Removal of medial wall of the lacrimal sac fossa, and if need be for visualization, a portion of the crest, with sphenoid punch (*arrow indicates anterior lacrimal crest*).



FIGURE 13 Radiofrequency dissector is used to open the medial wall of the sac (*arrow indicates sac wall*).

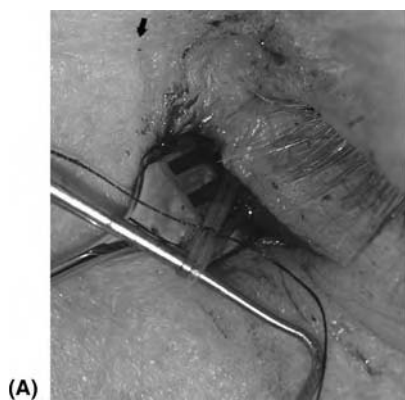


FIGURE 14 (A) The silicone is tied together in the sac with 6-0 silk. (B) The loop (*arrow*) at medial canthus is not tight and cannot be pulled further out.



FIGURE 15 A 12 french catheter is threaded over the silicone and a 4-0 chromic mattress suture is preplaced.



FIGURE 16 The catheter is inserted in the sac lumen and sutured to the anterior wall of the sac (*arrow*).



FIGURE 17 An anterior lacrimal crest incision and fine suture closure leaves nearly imperceptible scar.

which are removed at one week. Triamcinolone nasal spray is used bid. The drops and spray are continued until the catheter is removed which is at three weeks postoperative. The silicone is removed at three months postoperative.

The success rate for DCR is 90% to 95% (134,135). When it fails, there is fibrous overgrowth of the ostium. Repeat procedure can be done in a similar fashion. Recently, there has been the introduction of the use of mitomycin C (MMC) in an attempt to move the success rate closer to 100%, and to aid in the success of re-operations. A cottonoid is placed in the ostium prior to placement of the silicone stent and is soaked with 0.2% to 0.5% MMC. This can be left

in place for up to ½ hour. It has been shown that the ostium can remain larger following the use of MMC (136) and there is evidence that the overall success rate is improved when used during endonasal laser-assisted DCR (137). It is not known if there are long-term side effects from the use of this alkylating agent in this fashion.

Dacryocystectomy

The primary indication for dacryocystectomy is a neoplasm involving the sac. However, removal of the lacrimal sac provides an excellent alternative to DCR in patients with dacryocystitis, but minimal epiphora due to decreased tear production. The avoidance of an osteotomy and involvement of the nasal mucosa make the procedure easier than a DCR in an infirm patient. Patients with underlying inflammatory processes that would predispose them to failure of a DCR also should be considered for dacryocystectomy (138). Patients with dacryocystitis related to Wegener's granulomatosis can have chronic nasal-cutaneous fistulae following DCR and therefore they present another group that should be considered for dacryocystectomy (139).

An incision is made along the anterior lacrimal crest as is done for a DCR. The periosteum is elevated from the medial wall of the lacrimal sac fossa and dissection is then carried around the lateral aspect of the sac. A Freer periosteal elevator is useful for dissecting around the inferior aspect of the sac and into the nasolacrimal canal. The common canaliculus is divided and the fundus of the sac dissected free superiorly. A radio frequency dissector or bent needle-tipped cautery is helpful for the division of the nasolacrimal duct as far inferiorly as possible. Aggressive irrigation as well as intraoperative and postoperative antibiotics are needed in cases of dacryocystitis. The incision is closed with a fine suture.

Neonatal Dacryocystitis

Acute dacryocystitis in the infant causes an acutely distended lacrimal sac, a different picture from the more common epiphora, crusting of the lashes and regurgitation of mucoid or mucopurulent material when pressure was applied to the lacrimal sac seen with neonatal lacrimal obstruction. There is a rapid evolution of a significant inflammatory response and progression to perforation and drainage of purulent material through the skin.

Epidemiology

Nasolacrimal duct obstruction at the level of Hasner's valve at birth is relatively common with 6% to 10% of newborn infants having the obstruction (140,141). Pollard (142) reported that resolution of the obstruction occurred in 41% by six months of age by massaging and conservative management. Nelson et al. (143) reported that 107 of 113 cases resolved by eight months of age with conservative management; and, Peterson and Robb reported that there was continued resolution up to 13 months and by 18 months of age the passage was open in 85% of cases (144).

Acute neonatal dacryocystitis occurs in about 3% of infants with congenital lacrimal obstruction (145). It occurs rarely in the first week of life (146). Patrick found that newborn babies and 80% of premature babies have normal tear secretion on the first day of life (147), and it has been postulated that the sac contents (tears) could get infected during prolonged labor (148). Bilateral acute dacryocystitis has been reported to occur in a newborn premature infant (146).

Microbiology

As is true for adults, gram-positive cocci are responsible for the majority of cases of congenital dacryocystitis. However, *S. pneumoniae* is the most prevalent organism as compared to *S. aureus* in the adult. In 114 cases evaluated by Bareja and Ghose (149), gram-positive cocci constituted 57.9% with more than 50% of the cocci being *S. pneumoniae* (28.9% overall). *S. aureus* and *S. epidermidis* were isolated 13.2% and 11.4% of the time, respectively. Other organisms isolated were *Micrococci* (4.4%), *Pseudomonas aeruginosa* (4.4%), *Acinetobacter* (1.8%), and *Diphtheroids* (0.9%). One eye of the 114 studied had a mixed growth of organisms. As in other studies, a significant number had negative cultures (37/114), a finding the authors attributed to prior antibiotic therapy. They also noted that anaerobic bacteria were not adequately cultured and therefore could not be ruled out.

The most prevalent pathogen, *S. pneumoniae* was resistant to penicillin G, an antibiotic effective in the past. Culture results showed the greatest number of isolates sensitive to erythromycin (78.8%) and cloxacillin (72.7%), and few (15.1%) sensitive to gentamicin. The *S. aureus* exhibited 93.3% in vitro sensitivity to cloxacillin with an excellent in vivo response. While *S. epidermidis* has been felt to be normal flora, a number of reports suggest its pathogenicity in certain situations, and it should not be ignored (150–152). *S. epidermidis* was sensitive cloxacillin in all cases and also sensitive to erythromycin, gentamicin, and chloramphenicol in 80%.

Bareja and Ghose found no statistically significant correlation between the flora of the unilateral dacryocystitis and the conjunctiva of the contralateral eye or of the nasal flora. They concluded that conjunctival and nasal flora probably play no role in the causation of congenital dacryocystitis. They make the point that they found a changing pattern of bacterial flora and antibiotic sensitivity during therapy and suggest culture and sensitivity testing more than once during the course of antibiotic treatment (149).

Ghose and Mahajan (153) reported a study of 86 eyes in 66 patients with congenital dacryocystitis in which they looked specifically for fungal growth. Fungi alone were isolated in 12 eyes and in 14 eyes were isolated together with bacteria, for a total positive culture rate for fungus of 30.23%. Eleven types of fungi were isolated with *Candida albicans* the most prevalent (8/26). The authors noted that in the same part of India fungal cultures from healthy conjunctival cul de sacs is 6%. They suggested that the increase in fungal flora is probably aided by use of broadspectrum antibiotics in the presence of muco-purulent material. Fungi isolated probably represent fungal super infections by saprophytic organisms and not necessarily actual fungal dacryocystitis.

Treatment

The hallmark of treatment of congenital dacryocystitis is probing. Pollard reported 25 newborns treated for acute dacryocystitis occurring within the first three weeks of life (146). All patients were treated with probing, which resulted in resolution of the acute dacryocystitis. One patient continued to have epiphora and had subsequent probing with silicone intubation at nine months of age. Five of the 20 patients had one week of systemic and topical antibiotics prior to probing; the subsequent 20 patients had probing on the day of diagnosis without any prior antibiotic treatment. Culture was obtained on 10 patients with *S. pneumoniae* being present in six cases, *S. aureus* in two cases, and *Hemophilus influenzae* in two cases. Two cases of *S. pneumoniae* were resistant to penicillin. Other authors have noted a seeming emergence of penicillin G resistant pneumococcus in congenital dacryocystitis (150).

Lacrimal sac abscess may occur in the newborn from delayed treatment of nasolacrimal duct obstruction (154), and incision and drainage is recommended (155). Flanagan et al. recommend local and systemic antibiotics and suggest incision and drainage if the medical treatment does not work (156). While significant bacteremia and septicemia after infant nasolacrimal duct probing have been reported (157), there was no evidence of this in the cases treated by Pollard (156).

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Facial Burns: Management and Reconstruction

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INTRODUCTION

In the United States, nearly two million people are burned each year. Approximately 100,000 cases are severe enough to require hospitalization, and roughly 5000 deaths occur secondary to burn injury and related complications each year. As the face is exposed during most daily activities, it is one of the more commonly injured anatomic structures. Approximately 43% of burns admitted to one large burn center over a four-year period included a facial injury. Former burns of the face create some of the most emotionally disfiguring injuries and with such a high potential incidence, management of the facial burn patient remains a difficult clinical problem with a grave social impact.

The overall treatment goal for any burn is to restore form and function to the injured areas to the greatest degree possible. This is particularly important when reconstructing the facial area. As the face is one of the most expressive parts of the body, disruption of natural facial motion can potentially produce critical tissue distortion (1). The vital functions of vision, smell, hearing, breathing, speech, and eating all involve facial structures, and impairment in any of these functions can create significant disability with potential grave psychologic consequence. Precision in the initial management of facial burns as well as in their subsequent reconstruction is therefore of paramount importance.

INITIAL MANAGEMENT OF BURNS INVOLVING THE FACE

The initial management of any burn patient involves an evaluation of the entire body to assess the extent of injury and institution of resuscitation when needed. Burns to the face are not uncommonly associated with inhalation injury, particularly when the injury occurs in an enclosed environment. Signs of inhalation injury include carbonaceous sputum and oropharyngeal inflammation. When inhalation injury is a possibility, a carboxyhemoglobin level should be obtained. Treatment with oxygen in high concentrations should be initiated when appropriate. Though these aspects of burn care are critical, a complete discussion is beyond the scope of this chapter.

Burns of any nature or location are tetanus-prone wounds. Proper administration of tetanus immunization in patients with questionable tetanus immune status should be given at the time of initial burn injury.

The head and neck region accounts for approximately 10% of the total body surface area in an adult patient, yet the laxity of facial skin and rich blood supply can contribute to a disproportionate amount of fluid loss in this area. The resultant massive facial edema can distort facial anatomy and make airway management and intubation more difficult. For major burns involving the facial area, early intubation and placement of a nasogastric tube need to be considered before the edema becomes fulminant. Adhesive tape should be avoided in securing endotracheal and nasogastric tubes however as the underlying tissue can become macerated as edema develops. Head elevation should be maintained at 30° if possible to limit edema formation.

Facial burns often generate discolored epidermis in contrast to the blistering more commonly seen in other areas of the body. Gentle rubbing of the discolored areas is necessary to remove damaged skin during the initial burn debridement and evaluation. Soap of any type can irritate delicate areas of the face and can be harmful to the eyes. It should be used sparingly if at all for wound cleaning. Particular care is needed around the eyes, nares, and mouth to prevent debris and excess fluid from entering these orifices during wound cleansing as well.

Hair should be clipped or shaved from burned areas on the scalp as well as 2 to 3 cm beyond the burn. If the scalp is uniformly involved, the entire scalp should be shaved. Facial hair should be shaved in men burned in the hair-bearing areas of the cheek and lips. Hair removal allows more precise wound evaluation and treatment. Matted hair can hide damaged areas, facilitate bacterial proliferation, and prevent topical agents from reaching damaged tissues. Daily shaving in men will also facilitate the removal of debris and exudative crusting.

Techniques to limit cervical contractures are also important and include stretching exercises and positioning so that the neck is maintained in as extended a position as possible. Pillows that result in neck flexion should be avoided. A short mattress can be placed on top of a regular length one so the patient is forced to extend his or her neck over the edge of the shorter mattress. The TV can be positioned in a room so the patient is forced to extend the neck to see it. Neck collars can also be helpful. Early excision and grafting, when grafting is necessary, can limit the severity of subsequent contractures.

Initial facial burn injury assessment requires immediate assessment of visual acuity when possible. The eye should be examined and contact lenses removed if present. Edema may occlude eyelids rapidly making an assessment of visual acuity very difficult in the days following the burn injury. Early conjunctivitis related to smoke irritation is common, though more severe corneal injuries are not common due to the rapidity of the blink reflex. Rapid explosions however may surpass the speed of the blink reflex leading to corneal damage. Caustic chemicals can also get beneath the lids and damage the eye. Corneal damage should be evaluated with fluorescein if there is any suggestion of corneal injury. Eyes should be copiously irrigated if chemical contact is suspected or if burn debris is present. Eyes are best washed and debrided with plain saline as other agents may contribute to ocular irritation.

Care should be taken in removing any debris from the eyelash area that may contribute to eyelids sticking together. Trimming of the eyelashes can limit subsequent eye irritation and conjunctivitis caused by lashes that spontaneously shed (2). Eyebrows should not be shaved during initial debridement as they may not grow back completely (3).

Burns to the ear should be gently debrided with blister removal. The canal should be cleansed with warm water or saline to remove debris and later accumulated topical agents. Constricting bandages should be avoided over the ear as they can distort anatomic shape, interfere with blood supply, and potentially exacerbate the severity of the injury. Patients with severe ear burns should not be placed on pillows as the posterior margin of the ear may rub or stick to the pillow and cause additional damage. A "donut" pillow should be used to support the head when necessary.

Sulfamylon (mafenide acetate) cream is typically used to dress ear burns, as it is capable of penetrating effectively through eschar and protecting ear cartilage from infection. Iontophoresis with antibiotic solutions such as penicillin or gentamycin can be used to protect the ear from chondritis. Suppurative chondritis of the cartilage usually develops at three to five weeks following injury if it does occur and is a devastating problem. Suppurative chondritis often results in significant loss of ear cartilage.

Topical agents are used in the acute facial burn setting to control pain, prevent desiccation and slow bacterial growth (4). Though facial burns become infected less commonly than those in other anatomic areas due to the abundant blood supply in the region, treatment of burned facial areas with topical antibacterial agents is still appropriate. The face provides special challenges in terms of topical treatment, however, and there is no uniformity in how facial burn wounds should be managed. Bulky dressings, as are often used in other anatomic areas, can interfere with airway management and alimentation as well as vision and hearing. Less bulky dressings are therefore preferred in the facial area, which concurrently permits regular inspection of the underlying skin and its healing process.

Silver sulfadiazene (Silvadene) is commonly used as a topical agent for the treatment of many burn injuries because of its excellent antibacterial properties and limited toxicity. It is, by far, the most commonly used topical agent for nonfacial body parts in burns centers in the United States (5). There is much less uniformity in terms of the preferred topical agent for facial burns. Silvadene becomes relatively creamy when warmed by the skin in heated patient rooms. It can then run into the mouth, nose, or eyes, which is potentially harmful. In addition, the combination of Silvadene and wound exudate can lead to a discolored "mask" on the surface of the burn which can be somewhat difficult to remove and makes monitoring of the

wound more difficult. Because of these disadvantages, the use of petroleum-based ointments is typically preferred. Petroleum-based ointments are more likely to stay in the location in which they are placed. Agents such as bacitracin/neomycin/polymyxin (Neosporin) and mupirocin (Bactroban) have been studied for their antibacterial efficacy (6) and have been shown to have clinical advantage to nonantibacterial ointments. Ointments such as these are relatively occlusive and thereby limit pain while facilitating epithelialization. They are also relatively transparent and permit frequent monitoring of the burned areas. Furthermore, the bacitracin/neomycin/polymyxin agent is not injurious to the eye should it inadvertently be exposed to the corneal surface.

FACIAL BURN WOUND MANAGEMENT

Early excision and grafting of burn wounds is cited as a significant contributor to the overall improvement in mortality and outcome of patients with severe burn trauma over the last few decades (7). This technique can reduce the severity of contractures that often otherwise develop with secondary healing of deep burn wounds (4). Early excision and grafting can also permit the burn patient to return to society more quickly (8).

Although excision and grafting of deeply burned skin have become standard in most anatomic areas, it does not produce ideal results. Grafted areas never appear as they did prior to the injury in that the color, texture, and hair-bearing characteristics of grafted skin are never the same as native skin. Secondary healing can often preserve the characteristics of native skin. With its lush blood supply, the face has a greater ability to heal wounds secondarily when compared with other parts of the body. Because of this, delaying surgery for facial burns in order to maximize secondary healing is often preferred (Figs. 1 and 2). Proponents of this approach sometimes wait until granulation tissue is identified after eschar separation or after contractures develop before considering surgery (9). Krob and Jordon (10) proposed debridement with application of allografts as another method to facilitate secondary healing of facial burns.

Prolonged secondary healing can produce less desirable results. Prolonged secondary healing or delayed grafting on granulation tissue after eschar separation as suggested by Miller (9) may predispose to scar contractures or hypertrophic scar formation (11) (Fig. 3). Deitch et al. (12) found that in wounds that healed in less than three weeks, 33% developed hypertrophic scars, whereas in wounds that healed in greater than three weeks, 78% formed hypertrophic scars. Dark skinned individuals were also at a higher risk for scar hypertrophy (13). This study also noted that hypertrophic scars were less likely to develop in the head and neck than other anatomic areas. This was particularly true in anatomic areas with highly elastic skin, such as the submental triangle and the anterior neck.

Approaches to the early management of burn wounds vary at different burn centers. Most agree that excision and grafting are indicated for face burns that have not healed after three weeks (14–16). If a facial burn has not healed secondarily in that period of time, it is unlikely that there are enough preserved epithelial components to allow aesthetic secondary healing. In the past two decades, several authors have suggested that burns that appear deep enough to preclude healing within the three week-window should be grafted prior to the three-week



FIGURE 1 Child with facial burn.



FIGURE 2 Appearance after healing secondarily.

point. Jonsson and Dalsgaard employed an aggressive protocol where deep facial burns were excised and grafted in one procedure within four days after injury (17). This study reported good results in 16 patients. Hunt et al. excised and grafted individuals felt to have deep facial burns between four and 15 days after injury. Some were grafted at the time of excision and some in a delayed fashion. This group used sheet grafts of medium thickness that were splinted with a facemask and reported good results (18). Engrav et al. used a protocol where patients with significant facial burns were grafted 10–14 days after injury. Wounds were initially excised and covered with allograft. They were then grafted in a delayed fashion 48 hours later to limit graft loss due to hematoma formation. This group employed thick, unmeshed split thickness grafts from the scalp, which were applied to entire aesthetic units. Sutures over staples were used to fix the grafts in place and then the grafted areas were splinted postoperatively with pressure garments or Elastomere and foam (19). After using a similar protocol for 20 years, the same group published a follow-up article reporting on their results with this protocol in nearly 100 patients (20). The only significant change they made in the protocol over the 20 years was delaying the interval between excision and grafting for seven days to better assure the adequacy of the initial excision. Though satisfied with their protocol, they emphasize that it is only appropriate for 5% to 10% of patients with the deepest of facial burns. This study also stated that almost all patients had some sort of complications such as hypertrophic scars, ectropion, lip distortion, and/or nasal distortion.

There is no uniformity to early excision and grafting, even among those who support the approach. Different protocols use different time points for excision and vary in terms of whether the wounds are grafted at the time of excision or secondarily. These protocols also differ in terms of the thickness of the graft utilized. Fraulin et al. compared cosmetic and functional results in patients with facial burns who were treated in either a conservative or a more aggressive surgical fashion (21). They concluded that the best aesthetic and functional results are obtained in burns that can heal secondarily within 21 days. In patients with burns that healed secondarily after 21 days, the aesthetic and functional results were less satisfactory than



FIGURE 3 Hypertrophic perioral scarring after prolonged secondary healing of facial burn.

achieved with the early excision and grafting protocol promoted by Cole et al. (20). This group, however, could not demonstrate an advantage to grafting before 21 days as opposed to delaying grafting beyond that time frame.

In spite of persistent disagreement in various aspects of facial burn management, some basic concepts are becoming more widely accepted. It is clear that burns that heal secondarily within two to three weeks have the best aesthetic and functional outcomes, and if secondary healing within this interval can occur, it should be encouraged and facilitated. If the injury is clearly full thickness, early excision and grafting are most likely reasonable. If there is any question about burn depth, there does not appear to be any harm in waiting at least two weeks before proceeding with wound excision and grafting. More aggressive practitioners are likely to pursue grafting at that time point if wounds have not healed. Less aggressive practitioners may allow wounds more time for secondary healing and save surgery for a later time point for recalcitrant wounds and complications. It is difficult to state definitively that one approach is superior to another.

When grafting is required, local tissue tends to give the best result for facial reconstruction. In large burns, prime donor sites should be saved for the facial area if facial grafts will be required. The retroauricular and neck areas provide a limited amount of skin, which can be harvested in a full thickness manner. The scalp is one of the best donor sites for large split thickness grafts if it is available in that it will provide the best color match for the facial region, though the grafts will sometimes grow hair after transfer (22). The supraclavicular area, the upper chest, and upper arm can provide the next best color match for the head and neck region. The supraclavicular area can provide a limited amount of full thickness skin for grafting and larger split thickness skin grafts. Tumescence prior to graft harvest can facilitate the harvest of split thickness supraclavicular grafts. This anatomic area may be exposed by certain clothing, however, and it may be preferable to use a more hidden donor site if possible for those with this concern. Hypertrophic scars in these areas can also develop if thicker grafts are harvested.

Thicker grafts are generally preferred in that they retain more natural texture and pliability and have less of a tendency to lead to secondary contractures (23). The deeper dermal elements present in full thickness grafts have a greater ability to inhibit wound contraction than a similarly thick split thickness graft. Full thickness graft donor sites are generally limited in size unless the donor area is grafted. The lateral thoracic area is one source of large full thickness skin grafts (24). Tissue expansion can be utilized to expand full thickness donor sites and increase the utility of full thickness grafts from other areas (25,26). A judgment sometimes needs to be made whether to utilize a thicker graft from a less desirable donor area or a split thickness graft from the head and neck region. Thick split thickness skin grafts from a location above the clavicles are generally more likely to produce better aesthetic results than thicker grafts from a less favorable donor site. Truly thin grafts from any donor site should generally be avoided in that they will not provide the best aesthetic result and are likely to lead to secondary contractures.

Most agree that grafting regional aesthetic units (Fig. 4) as described by Gonzalez-Ulloa optimizes aesthetic results (27). This approach avoids a patched appearance in that the scars are relatively concealed in the natural boundaries of the face. If the entire face needs resurfacing, it should be treated as one large subunit, so that as much uniformity as possible can be created across it. If the entire face requires grafting, the choice of donor site is less critical in that the color of the skin will be consistent provided that the entire face is grafted with the same donor site skin. All grafts are subject to hyperpigmentation and should be protected from sunlight for a minimum of 6 to 12 months.

Flaps are an alternative for coverage of extensive burn defects or deformities. They, however, are typically a second choice in the acute setting. There are circumstances however where flaps may be required in the acute setting including severe burn defects that expose bone or cartilage or if an extensive burn defect involves irradiated tissue. Flaps of adjacent tissues can provide excellent cosmetic reconstructions for some small cheek burns and can be the wound closure method of choice. They have the advantage of limiting secondary wound contracture, but tend to provide more bulk than is optimal for an ideal aesthetic restoration. When flap coverage is required, secondary debulking can frequently improve the surgical result. When exposed bone or cartilage is present, an alternative to the direct transfer of a flap is the utilization of the "crane principle." With this technique, a flap is rotated to provide coverage of the exposed area and allowed to mature for two to three weeks. This allows for revascularization of the deeper flap

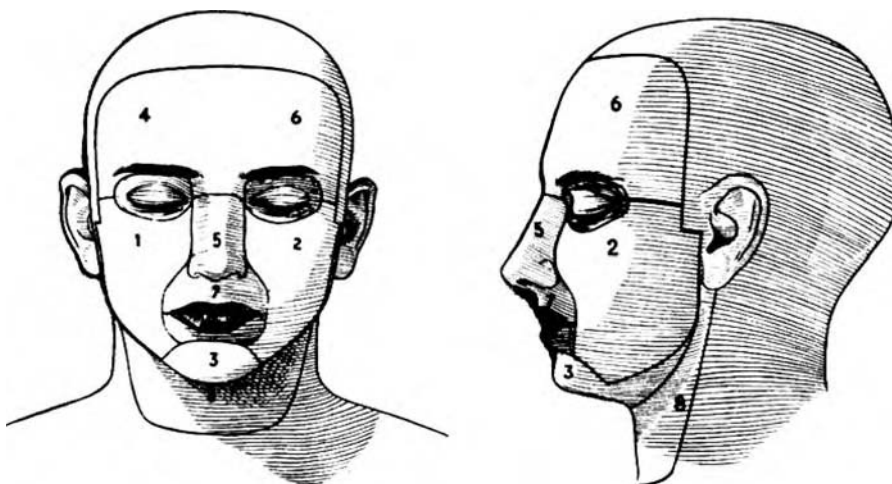


FIGURE 4 Aesthetic subunits as defined by Gonzalez-Ulloa.

elements to a degree that a vascularized bed is left after more superficial portions of the flap are rotated back to its native position. The vascularized bed can then be covered with a skin graft.

ADJUNCTIVE NONOPERATIVE TECHNIQUES

Numerous adjunctive nonoperative techniques are currently used with the goal of improving the aesthetic results achieved in facial burn management. Rayer first described the use of pressure in the management of abnormal scars after burn injury in 1835 (28). The use of pressure to limit hypertrophic scarring after burn injury has more recently been popularized by Larson et al. (29). Larson et al. empirically noted significantly improved results after continuous application of pressure at 24 mmHg or greater for 6–12 months after injury or grafting. This group, however, did not evaluate this modality in a randomized prospective fashion, but their positive uncontrolled studies prompted the technique to be widely utilized. Kischer et al. evaluated the modality experimentally and noted more organized collagen bundles and fewer collagen nodules histologically in scars treated with pressure for three months (30). This study also noted increased levels of hyaluronic acid and decreased levels of chondroitin sulfate. Kischer et al. speculated that pressure induced a relatively hypoxic state in the scar, and that this environment led to degeneration of fibroblasts within the scar resulting in diminished collagen synthesis. This group also speculated that the degenerating fibroblasts released enzymes that facilitated the breakdown of mucopolysaccharides in the wound, further contributing to scar softening.

More recently, Tredget et al. have further considered the possible mechanism by which pressure might limit hypertrophic scar formation as well. They examined hypertrophic scar tissue samples and noted increased water content, decreased collagen (hydroxyproline) content, increased uronic acid (a component of glycosaminoglycans except keratan sulfate), and increased amounts of hydrophilic sugar chains associated with glycosaminoglycans as compared to normal skin tissue samples and normal scar tissue (31). They speculated that minimizing the accumulation of edema with customized elastic compression could help prevent the development of hypertrophic scar tissue. The expulsion of water, however, is reversed rapidly when compression is removed because of the continued presence of the glycosaminoglycan sugar chains that attract water back into the hypertrophic tissue region. Therefore, they suggest that compression is required on a continuous basis for an extended period of time to be effective.

Reno et al. also considered possible mechanisms for a positive effect of pressure on scarring (32). They speculated that pressure might induce favorable changes in hypertrophic scars by inducing the release of PGE_2 , which could stimulate increased collagenase production based on the experimental data.

Though the use of pressure inducing devices and garments has become widespread, the efficacy of the modality had been questioned. Chang et al. prospectively randomized 122 patients with burns that either required grafting or healed secondarily in greater than 14 days to one of two treatment regimens (33). One group received no pressure garments while the other group was treated with pressure therapy. The endpoint of the study was scar maturation, which was defined as the point when less than 10% of the wound demonstrated scar hypertrophy or hyperemia. In this study, both treatment groups reached a comparable endpoint in a similar amount of time. They specifically excluded facial burns, however, from their study due to ethical reasons.

In spite of its unproven efficacy, pressure continues to be widely utilized as an adjunctive modality to limit scar hypertrophy and facial distortion after facial burn injury. Pressure therapy is generally initiated soon after the wound has epithelialized. Pressure garments should typically be worn 24 hours a day during the entire process of scar maturation, which can be up to two years. Pressure garments do have limitations in that the garments are expensive and somewhat uncomfortable to wear.

Both rigid and nonrigid materials have been utilized for the fabrication of facial masks. The uniformity of pressure generated under rigid and elastic masks is very similar (34). The rigid masks are generally created from thermoplastic materials. Initially, petroleum jelly is applied to the face and an alginate mold is made. A plaster facial model is then generated from the alginate mold. Thermoplastic material is then utilized to generate a mask that conforms to the plaster facial model. Masks are custom-made for each individual and frequently require modification to assure an accurate fit. They are held into position via elastic bands around the head. More recently computer-aided models have been used to generate masks without creating the plaster facial models (35). These masks are either clear or opaque with clear masks being potentially advantageous for permitting direct inspection of skin to mask pressure areas. Rigid masks have also been utilized to facilitate graft take by applying the mask immediately after the graft is applied (36).

The masks are labor intensive to produce and, in children, a general anesthetic is sometimes required to produce the required mold. In addition, masks do not provide the flexibility required in the jaw area. Probably for these reasons, rigid masks are used much less commonly than elastic masks (37).

The uneven contours of the facial area make the application of even pressure to all aspects of the face difficult to accomplish with elastic garments. The juncture of the nose and cheek is a particularly difficult area in which to generate the appropriate degree of pressure. Custom inserts are often used to even pressure, particularly in difficult areas such as the nose-cheek junction. Elastic masks need to be replaced every several months to maintain an adequate degree of pressure. Masks can at times lead to skin breakdown and ulceration when appropriate fit changes with scar maturation.

Children provide particular challenges for the utilization of pressure garments. They may find pressure garments unpleasant and often will not keep them in place. In addition, rapidly growing children must have masks and devices of any sort refitted regularly to avoid excessive pressure and either tissue damage or growth restriction (38).

Garments and splints are also used to limit contracture formation after wound closure. Larson et al. (29) popularized the use of splints for all burns across joints, including the neck, for the limitation of contractures. Nasal dilators have also been used to limit nostril constriction after severe nasal burns. Oral contractures resulting in microstomia after perioral burns may be limited by devices splinting the mouth open (39). There are a number of devices available with some being fixed to the teeth. The relative efficacy of different devices has not been evaluated.

Scar contracture as a result of burns in the perioral area can result in dentoalveolar deformities, particularly in children and immediately after tooth extractions. The use of pressure garments may exacerbate these changes. Dental splints may limit the degree of deformity that is generated. Splints are typically worn for 6 to 12 months and outcomes are often age-dependent, depending on patient compliance.

Pressure can also be delivered through massage, which many feel to be beneficial in limiting scar hypertrophy. It is felt to increase joint mobility by softening or remodeling scar

tissues and by freeing fibrous bands. The technique consists of firm, slow massage, and stretching of the evolving hypertrophic area after application of a skin emollient. The actual massage motion is felt to be more crucial to minimizing hypertrophic scar formation than the actual emollient agent used and some prefer not using an emollient. Massage is performed by the patient or family member at least twice daily for 5 to 10 minutes to each area treated. The efficacy of massage as a therapeutic modality has not been conclusively demonstrated.

Silicone gel sheets have also been utilized to minimize hypertrophic scar formation after facial burn injury. Silicone gel sheets can be worn as long as 24 hours a day though care must be taken with hygiene to avoid the development of contact dermatitis (40). If skin irritation limits the amount of time the sheets can be utilized, efficacy may still be achieved if the sheets are used for at least 12 hours a day. The mechanism by which silicone gel might affect scar biology is not known. It has been theorized that silicone gel may exert its effects by increasing scar temperature which would, subsequently, enhance the activity of collagenase which is known to increase severalfold over 1° to 2° Fahrenheit of body temperature (41). Its therapeutic benefit may also relate to improved maintenance of hydration of the stratum corneum in that it does lead to improvement in skin hydration. Quinn demonstrated that silicone gel produces minimal pressure, does not limit oxygen transmission, does not alter skin temperature, and does not result in transmission of chemicals into the skin and popularized the concept that the mechanism of action was related to skin hydration (40).

In a prospective, controlled trial evaluating the effectiveness of silicone sheets on a group of hypertrophic scars, universal clinical improvement was noted in scars treated for at least 12 hours a day for eight weeks (42). In a prospective evaluation of silicone and nonsilicone gel dressings for keloids and hypertrophic scars, primarily in nonfacial locations, the two dressings equally improved scar color and induration and limited itching and pain (43). It is, therefore, unclear whether it is the silicone or simply the gel that produces efficacy in scar management. Silicone gel is frequently used in conjunction with pressure making it difficult to assess the relative benefits of the two modalities individually.

After the wound has epithelialized, topical vitamin E (alphatocopherol), topical steroids, and other agents are often used with the goal of softening newly forming scar tissue. Vitamin E could potentially have therapeutic effects either through its antioxidant characteristics or possibly its inhibitory effect on collagen synthesis (44). However, when the effect of topical vitamin E on scarring has been evaluated prospectively in burn scars as well as other scars, no beneficial effects have been demonstrated (45,46). Triamcinolone 0.025% has been used topically in a similar fashion to potentially improve scarring with the added potential additional benefit of relieving itching. The efficacy of topical steroids in scar management has not been confirmed in prospective studies (45).

Intralesional injections of triamcinolone have been demonstrated to effectively diminish the size of established hypertrophic scars and keloids. Up to 120 mg of triamcinolone can be injected intralesionally on a monthly basis without risk of systemic effects. Over 90% of hypertrophic scars and keloids respond to intralesional triamcinolone (47). Triamcinolone injections most likely produce benefits by inhibiting transcription of certain matrix protein genes (including alpha 1[I] and alpha 1[III] procollagen, fibronectin, TGF-beta, and other cytokines) as well as reducing alpha 2-macroglobulin synthesis, a known inhibitor of collagenase activity (48). Adverse side effects from corticosteroid injections include pain at the injection site, atrophy of the scar or surrounding tissue, telangiectasias and rarely tissue necrosis and ulceration or cushingoid habitus (31).

The injection of calcium channel blockers such as verapamil and/or calmodulin inhibitors has been utilized to ameliorate hypertrophic scars as well (49). These classes of drugs are known to induce collagenase gene transcription and decrease the production of matrix molecules such as collagen.

Lasers as well as chemical peels and dermabrasion have been utilized to render pigmentation in scars and grafts more uniform with the remainder of the face. The effects of these interventions tend to be somewhat unpredictable, though good results have been reported. When the goal is to diminish erythema in scar, lasers such as the pulsed tunable dye laser can be effective (50).

RECONSTRUCTION AFTER FACIAL BURNS

Reconstructive Ladder After Burn Scar Excision

The reconstruction plan for facial burn is often a multistaged process that is determined collaboratively with the patient, the patient's family, the plastic surgery team, and the patient's rehabilitation therapists. The timing of any postburn reconstruction requires surgical judgment in order to determine the best time to intervene. An overall plan must be developed for the management of the entire head and neck area. This should include the development of priorities in terms of reconstructive and rationing of the most satisfactory donor areas. The surgeon needs to assure that healing avoids a two-dimensional appearance created by scar contraction around projecting areas like the nose and ears. A complete appreciation of the tissue defect and a management plan that addresses it minimizes secondary problems. When an accurate anatomic form has been re-established, problems related to scars and skin color become less apparent.

Multiple stages are often utilized, and sometimes complex techniques are beneficial. Each of the stages needs to be carefully considered so as to maximize the gain that is achieved and to minimize the need for secondary procedures. The patient needs to have a realistic idea of what can and cannot be achieved. Unfortunately, even the most skilled reconstructive surgeon cannot recreate a completely natural appearance for the patient with severe facial burns.

Aesthetic principles need to be carefully considered in developing a reconstructive plan for facially burned patients. This involves consideration of aesthetic units (Fig. 4) and avoidance of the creation of patches. It also involves the consideration of facial symmetry and doing similar things to both sides of the face whenever possible. If only one side is injured, obtaining an optimal color match for the uninjured side is a prime priority.

In many circumstances, the passage of time will permit a facial burn to mature and develop a texture, coloration, and contour similar to normal healthy skin. It is often not possible to initially predict which facial burns will require multiple reconstructive procedures versus which facial burns will improve to a satisfactory level of function and aesthetics without operative intervention. Allowing for time and scar maturation clarifies which scars are adequate without revision and which will require surgical modification.

Though time remains an ally, reconstructive procedures cannot be delayed if significant complications related to scar contracture develop. These are particularly common in the eyelids, neck, and perioral area. In children, there is the additional consideration of whether a scar has the potential to limit facial growth. Restrictions in the nasal area can limit nasal development. Restrictions around the mandible or teeth may distort the teeth or limit mandibular growth. Scars that may be restricting growth should be addressed at an early time point.

As previously mentioned, wounds that heal in less than three weeks form hypertrophic scar 33% of the time whereas in wounds requiring more than three weeks to heal, 78% will develop hypertrophic scar (13). Complications related to scarring, therefore, will be more common in a burn wound that has healed secondarily over a protracted period. If it becomes clear in a relatively short period of time that a contracture or unaesthetic scar will not improve with time, there is no reason to arbitrarily delay a reconstructive procedure.

In addition to considering the nature of the scar, issues related to the patient must be considered. The readiness of the patient to undergo a reconstructive procedure both physically and emotionally must be placed in the timing equation. Furthermore, the relative priority of reconstruction of the facial area must be considered in relationship to reconstructive needs in other anatomic areas.

Wound contracture can create significant difficulties for the facially burned patient, and many reconstructive procedures address problems with form and function generated by the wound contraction process. An accurate diagnosis of the source of the contracture is required in order to develop an effective treatment plan. Contracture can be classified as extrinsic or intrinsic. An intrinsic contracture is a direct contracture of the affected area, for example, shortening of the lower eyelid from a burn of the lid itself. An extrinsic contracture results from a tissue deficiency in an adjacent body part, for example, eyelid ectropion as a result of a burn of the cheek. Both can occur simultaneously. Frequently, extrinsic contracture requires release whereas intrinsic contracture requires reconstruction.

Areas of the face that are particularly susceptible to contracture formation include the upper and lower eyelids, the upper and lower lips, and the neck. Contracture formation on the eyelids will lead to the development of chronic conjunctivitis and possibly corneal ulceration. The formation of lip contracture can make oral intake difficult if not impossible. Delaying treatment of lip contracture in children can also contribute to distorted, labial inclining growth of teeth which can ultimately distort the normal bite (51). As mentioned, hypertrophic nasal and cheek scars can also impair normal nasal and mandibular growth in burned children. Scar contracture that may be contributing to any of these problems should be addressed as early as possible.

In choosing the best reconstructive option for any area, the simplest method that will produce the desired outcome is generally preferable. Simple excision of thickened or widened burn scars can often produce significant improvement in an overall aesthetic and functional result. The healing of a surgical incision uncomplicated by the inflammation associated with the original burn injury can frequently result in an improved scar. A Z-plasty can frequently be a valuable adjunctive procedure to direct scar excision. Z-plasties reorient scars and provide a gain of length along the scar line, thereby reducing skin tension related to a scar contracture. Z-plasties with scar excision can provide significant improvement in the scars along the perimeter of grafts at the juncture of aesthetic units such as in the nasolabial scars and para-alar nasal regions.

Skin grafts have significant utility in the reconstructive setting as well. The same issues that apply to primary facial grafting persist. Attention to the aesthetic unit principle remains appropriate as well. Donor sites in the head and neck area are preferred in that the color match is better. Full thickness grafts provide better texture and pliability than split thickness grafts in addition to limiting secondary contracture to a greater degree (52–54). It is often necessary to use split thickness grafts for larger areas, such as in significant cervical contractures or when an entire aesthetic unit requires coverage, in that full thickness grafts of the desired size are not readily available. There is virtually never an indication to mesh a graft to the facial area.

Local flaps can be useful for the reconstruction of limited areas of tissue deficiency and have the advantage of providing natural appearing skin coverage. Flaps can be particularly useful in the nasal and cheek areas. Flaps are sometimes preferred because they resist secondary contracture to a greater degree than skin grafts, and they can effectively provide correction of even severe contractures in the neck and axillary areas. In the instances where flap reconstruction is required or chosen, attention to aesthetic units can often improve the aesthetic result (55).

Microvascular transfers are sometimes an effective method for transferring large amounts of tissue to completely replace aesthetic units (56). Total face reconstructions have been carried out using bilateral microvascularly transferred scapular flaps (57). For extremely severe deformities, innovative techniques such as the microsurgical transfer of prefabricated flaps or the use of a microvascular crane may have utility (58,59).

Finally, tissue expansion facilitates burn reconstruction by expanding peripheral skin and permitting reconstruction with sufficient skin of matching color, texture, thickness, and sensation while minimizing the donor defect. The disadvantages of tissue expansion include a minimum of two procedures to complete the reconstruction and an intervening period where the patient may have to deal with a very unusual appearance. The benefits of the technique make it useful in many clinical situations in spite of these disadvantages.

Reconstruction of Specific Structures

Scalp

Scalp alopecia is a common sequelae of burns of the head and neck region. Young children have particularly thin scalp skin and are prone to this complication of burn injury. The hair-bearing tissue of the scalp is relatively unique, and therefore, reconstructive modalities are limited by the amount of appropriate tissue available.

Small areas of alopecia can be treated by direct excision with wound closure by advancement of surrounding hair-bearing skin. For slightly larger areas of alopecia, serial excisions of involved areas can be successful when this technique is used. Procedures are generally spaced at least four to six months apart to allow for adequate relaxation of the mobilized tissues. When carrying out serial excisions, an appropriate amount of advancement is required from the surrounding

tissues to allow wound closure before committing to the amount of scar to be removed at each stage. Excessive tension can compromise the flap, or can lead to secondary stretching of the scar.

Tissue expanders are an ideal mechanism for reconstruction of large areas of burn alopecia (60). As a rule, if it is anticipated that more than two serial excisions will be required, a tissue expander is a better reconstructive alternative to serial excisions. It will also require a minimum of two procedures but provides the advantage that 30% of the scalp can be reconstructed by the treatment regimen. The clear disadvantage of expanders is that a rather odd appearance is created during the period of expansion. Two or more expanders are often used at one time to expand all available hair-bearing tissues. Expanders are placed in the subgaleal plane through incisions that can be utilized during flap advancement. If possible, incisions adjacent to the burn scar are to be avoided in that they can be prone to disruption during expansion. Incisions for advancement of the expanded flaps need to be planned to allow for maximal advancement of the hair-bearing tissue. If the base of the flap is to be compromised in any way by the planned incisions, incorporation of a major blood vessel such as a temporal or occipital vessel may increase the safety of the procedure. Capsulotomies may be required to maximize advancement of the expanded tissue for larger defects.

The sideburn area requires particular attention. A natural appearing hair pattern requires hair in the temporal sideburn areas. In the male, in particular, hair growth in the normal down and posterior direction is required for a natural appearance. This needs to be considered in planning the transfer of tissue to this area.

For larger defects, secondary expansion of the expanded scalp flaps can be carried out to extend the reach of hair-bearing flaps. Using serial expansions, 50% or more of the scalp can be reconstructed. The process of expansion does increase the distance between the hair follicles resulting in thinner hair, though hair density is adequate to provide an excellent reconstruction in most cases.

For burns damaging more than 50% of the scalp, the goals of reconstruction must be compromised. It will generally be impossible to completely recreate a natural appearing hair bearing scalp. Nonhair-bearing flaps may be necessary to cover injuries where bone is exposed, and free flaps are often required in this clinical situation. Once wounds are closed, wigs can provide a very adequate aesthetic appearance. Alternatively, hair-bearing flaps can be positioned so as to provide at least a frontal hairline to disguise the loss of hair either by direct rotation or by microvascular transfer.

Forehead

Reconstruction of forehead deformities is limited by the minimal distensability of forehead tissues. In spite of this limitation, smaller burn scars can still be improved by local excision or by the transfer of adjacent tissue. Serial excisions may be beneficial for slightly larger defects. For more extensive defects that encompass less than 50% of the forehead, tissue expanders provide an excellent reconstructive option (61). If more than 50% of the forehead is involved by burn scar, a full thickness or thick split thickness skin graft is best used to reconstruct the forehead as a complete aesthetic unit with great care being taken to extend the graft to the hairline and caudally to the eyebrows (27,62,63). For deeper injuries that expose bone, a scapular or forearm free flap that replaces the entire aesthetic unit can produce a reasonable result. Alternatively, one can temporarily transfer scalp tissue and employ the "crane principle" to provide a vascularized bed that can accept a graft.

Eyebrow

Eyebrows add significantly to the expressivity of the face and reconstruction of lost eyebrows can frequently be a valuable component of a comprehensive facial reconstruction. Reconstruction should be delayed until the eyelids and forehead have been reconstructed to assure that the position of the reconstructed brow is not altered by subsequent reconstructive procedures.

The use of a cosmetic eyebrow pencil to draw in eyebrows is adequate either temporarily or occasionally as a permanent alternative to a definitive reconstruction. Men are less likely to utilize an eyebrow pencil than women. A similar but permanent solution to eyebrow deficiency is a tattoo. Like the eyebrow pencil, this provides a two-dimensional result that is not entirely natural.

For those who prefer a hair-bearing eyebrow, either grafts or flaps can be used. Grafted brows tend to be a thinner while brows reconstructed with a flap tend to be bushier. Either method can be supplemented with an eyebrow pencil. The method chosen must take into consideration the nature of the opposite brow if it is not burned. It must also consider the local tissue, in that grafts will not take well in a heavily scarred environment.

The location of the reconstructed brow is best chosen with the patient in an upright position to assure the most natural brow positioning. Either strip grafts or micrografts can be utilized if a graft method is preferred (64). The technical aspects of micrografting have improved significantly over the last decade with improved graft survival, though a well-founded comparative study of the two methods has yet been performed. The direction of normal hair growth must be considered in graft placement. The hairs of the medial brow tend to grow more upward and outward while hairs in the central and lateral brow grow upward and laterally. Grafts should be positioned so that their growth mimics that of the natural brow. The usual donor site is the scalp, and scalp hair grows rapidly and is stiffer than eyebrow hair. Occasionally, grafts can be taken from the contralateral eyebrow to give a more natural and symmetric appearance.

Island pedicled flaps from the temporal scalp are the most common flap used for brow reconstruction. The flaps are based on the anterior branch of the superficial temporal artery, and this vessel must be uninjured if a flap is to be utilized (65). The flap is tunneled from the temporal scalp to an incision placed in the desired brow location in the vicinity of the supraorbital rim. Care must be taken to assure that the flap is positioned medially and low enough. Abnormally elevated brow positions are particularly hard to correct. Temporal scalp flaps are often subject to follicular misalignment, which prevents the best cosmetic result. The hair is also generally fuller than is normally present in eyebrows.

Eyes and Eyelids

Eyelids are not one of the most commonly injured facial structures in that they are somewhat protected within the orbit, but can be involved in extensive facial burns. Reflex blinking and squinting in response to smoke and heat usually protects the cornea and lid margins. Explosions may occur too rapidly to allow blinking, and can produce corneal damage.

Most flame injuries produce only a partial thickness injury to the eyelid skin though more severe heat exposure can produce an injury that extends through the skin into the orbicularis muscle. Rarely are deeper structures such as the levator involved. The worst injuries occur when an individual loses consciousness and lies in proximity to extreme heat. In such situations, the entire lid can be lost and the underlying eye can be severely damaged.

The healing of even partial thickness eyelid burns can result in a contracture that produces ectropion. Either the upper eyelid, lower eyelid or both can be involved in this process. Ectropion produces exposure of the eye that at the minimum produces conjunctivitis. Mild to moderate conjunctivitis should be addressed early with topical ophthalmic ointment and artificial tears to limit corneal drying. Corneal drying can lead to ulceration and loss of vision. This is more likely to occur with upper eyelid ectropion in that the upper lid is most responsible for corneal protection. The patient should be examined both while awake and asleep to assure that the cornea is being protected. If it appears that the cornea is at risk for drying, ointment, and artificial tears can be supplemented by creating moist occlusive chambers over the eyes. Some alternatively use scleral lenses to protect the cornea. Tarsorrhaphy and standard contact lenses should generally be avoided in that they tend to create more problems than they solve.

In circumstances where ectropion and conjunctivitis are more severe, scar release and grafting in the first weeks after the burn injury should be performed (66). When intervention is performed early after the burn injury, secondary procedures are likely to be required for recurrent contracture. This approach assures better protection of the eye than the alternative of depending on an ointment and eye chamber while waiting to perform one definitive procedure once scars have matured. When early ectropion release is carried out, prime donor sites are frequently reserved for a definitive contracture release procedure at a later date. If the eyelid skin is too damaged to allow for ectropion release and grafting, conjunctival flaps can be used for corneal protection (67).

Definitive reconstructive procedures are ideally carried out six months after injury when the scar has matured. For problems with ectropion, an accurate diagnosis must be made as to

whether the tissue deficiency is intrinsic within the eyelid itself, or is extrinsic as a result of contractures in the cheek or neck. A combination of the two is also possible. Generally, the most severe contractures are addressed first. The contracture must be completely released and this often involves extensive releasing incisions extending from medial to the medial canthus to lateral to the lateral canthus. It is important to be aware of the normal eyelid contour, and the appropriate location of the palpebral fissure to assure that an adequate release is obtained in order to recreate a natural eye contour. It is critical that an adequate amount of graft is utilized. Overcorrection of the defect is preferred. In order to compensate for recurrent contraction-postoperatively. In the upper lid, the incision lines are generally either placed just above the lash line or in the tarsal crease though the tarsal crease incision is generally reserved for contractures limited to the upper portion of the upper eyelid. In the lower lid, the incisions are generally placed in a subciliary location. The incisions are sometimes extended laterally and medially in a Y-shaped fashion to allow a more complete contracture release. After incision, the lids sometimes require unfurling if they are significantly contracted. Care must be taken to protect the orbicularis oculi muscle in either lid unless there is clearly scar contracture extending into the muscle itself. Less severe skin deficiencies of the upper eyelid are addressed with full thickness skin grafts harvested from the contralateral eyelid when possible. A full thickness skin graft from the retroauricular region works optimally to replace more extensive deficits of eyelid skin. Thicker full thickness grafts should be avoided in that they do not drape and fold well, as is required for normal upper eyelid function. The less mobile lower lids can tolerate thicker full thickness grafts, though split thickness skin grafts are used if there are no appropriate full thickness donor sites. When larger grafts are required, the aesthetic unit of the eyelid should be considered in planning graft orientation.

When planning graft size, the defect should be stretched to its maximal extent and the largest possible graft utilized to limit the likelihood of recurrent contracture. Though the upper and lower eyelids on the same eye can be addressed simultaneously, this precludes the exaggerated correction of each lid that is desirable to limit recurrence and may not be the preferred approach. It is preferable not to address both eyes at one time, in that the bolster dressings generally used will occlude vision for some time after the procedure.

Medial as well as lateral canthal folds can be corrected with Z-plasties. Adjacent tissue transfers can be used to replace limited amounts of missing eyelid skin. Small laterally based flaps from an unburned eyelid can be used to resurface limited defects of the lower eyelid. Bipedicled Trippier flaps can also be transferred from the upper lid to the lower lid (68). Superiorly based naso-labial flaps are another alternative for lower lid coverage. Free tissue transfers may be required for eyelid reconstruction for the most extreme burns.

Nose

Burns of the nose are relatively common given the prominent position of the nose on the face. Deformities related to nasal burns are frequently not evident soon after injury but can become apparent as the wounds heal secondarily through epithelialization and scar contracture. Because of its prominence, reconstruction is particularly important.

Scarring in the region of the nostrils can lead to nasal foreshortening with an elevated tip and nostril eversion. This deformity creates accelerated air flow through the nose which can result in mucosal drying and bleeding. Alternatively, scarring in the region of the columella and alar base can create strictures, which limit the nostril aperture. Both problems require treatment. In children, scars of the nasal tip may impede the normal growth of the bone and cartilage, particularly in the anterior septal region, and compound the burn-induced deformity.

In planning nasal reconstruction, one must assess the degree of deformity in the mucosa, nasal cartilage and the skin envelope in that each of the components of the nose must be addressed if an accurate reconstruction is to be accomplished (Fig. 2). The degree of tissue loss in the region of the nasal tip is often underestimated if the three-dimensional nature of the nose is not considered.

Judgment is required in planning what scars require release and which must be excised to recreate the desired nasal contour. Thickened, hypertrophic scars on the nose often require excision to allow for a natural reconstruction. Excision of the scar can sometimes allow cartilage to rebound to a more normal contour. For less extensive scars that still result in nostril eversion,

a release of tissue along the alar rim may be all that is required to recreate the normal anatomy. Nasal lining must sometimes be mobilized aggressively for the overlying tissues to return to a normal position. For significant contractures involving the entire nasal tip, a complete scar release taken from the base of the alar crease into the tip may be required to allow for recreation of a normal contour. The release must sometimes be taken down to the mucosa between the upper and lower lateral nasal cartilages in order to achieve the degree of release required.

After scars have been adequately released or excised and as normal a contour as possible has been re-established, tissue revision or replacement needs to be considered. Intranasal grafts are sometimes required to replace deficient lining tissues. For extensively scarred and stenotic nostrils, application of a full thickness skin graft after complete scar excision can be effective. These grafts frequently require stenting for up to a year to prevent recurrent stricture. Less severe intranasal linear contractures may benefit from Z-plasty corrections. Occasionally, flaps of perialar or lip tissue can be turned intranasally to provide nasal lining and correct strictures.

Cartilage grafts from the ear or less commonly the costal margin may be required to replace damaged structural elements. Composite grafts from the root of the helix of the ear can be used to replace limited composite nasal defects of the nostrils.

Greater or lesser amounts of skin may require replacement. If intranasal and cartilaginous grafts are necessary, flap coverage as opposed to simply grafting will generally be necessary for nasal reconstruction. For severe injuries that require complete nasal resurfacing, the nose should be treated as a single aesthetic unit. It may be appropriate at times to consider nasal aesthetic subunits if only a limited amount of the nose is damaged.

When replacement of superficial skin is required and the underlying nasal tissues are well vascularized and relatively undamaged, a full thickness graft can produce an excellent aesthetic result. The postauricular area will not provide adequate skin to resurface the entire nose, though the supraclavicular area will. If this site is not available, split graft donor sites from the upper body produces a better color match than those on the lower body. If the cheek is not excessively damaged and does not require grafting, a better color and texture match can sometimes be achieved with flap reconstruction from either the nose itself or forehead, if those tissues are available.

Columellar defects can be difficult to reconstruct. Alternatives include superiorly based nasolabial flaps, composite grafts from the ear and, occasionally, forehead flaps. Limited tissue opposition in a repeatedly scarred area sometimes limits the effectiveness of composite grafts in this area.

For extensive defects where all or most of the nose is destroyed, traditional methods of nasal reconstruction are applicable. The forehead flap combined with additional flaps or grafts for nasal lining and bone or cartilage grafts can produce excellent results (Figs. 5–7). Tissue expansion may allow for the use of a forehead flap even in patients with somewhat compromised foreheads. If only the lateral portion of the forehead is available, a scalp flap using lateral forehead tissue with a blood supply derived from the adjacent and contralateral scalp can be useful. When local tissues are not available, a Tagliacozzi flap from the arm (69) or a free tissue transfer can be useful. The color match provided by distant flaps is frequently not ideal, and they frequently require one or more revisions to create a reasonable nasal contour.

Cheek

The purpose of any reconstructive procedure for the cheek is to resurface badly scarred areas with skin that appears as much like native cheek skin as possible. The goal is a surface that is uniform and symmetric with the opposite cheek and as normal in color in texture as possible. In males, the location of hair bearing tissue must also be considered. Maintenance of a normal beard pattern is desirable in males, both so a normal beard can be grown and because hair-bearing facial tissue has a slightly different colors and textures than other cheek skin. These goals may not be able to be achieved completely, and judgment is required in assessing which of the goals to compromise in optimizing the aesthetic result. Each case requires an individualized approach.

Smaller thickened scars may benefit from simple excision. Scars should be positioned in relaxed skin tension lines whenever possible. Z-plasties or W-plasties can sometimes be useful for breaking up linear, contracted scars. Serial excisions of larger areas can also sometimes be useful.

Larger damaged areas often benefit from resurfacing with a cheek flap or larger cervicofacial flaps. These flaps can be based inferiorly or laterally, depending on the reconstructive



FIGURE 5 Nasal deformity after severe burn.

need. Inferiorly based cervico-facial flaps can be extended laterally to include mastoid skin from the retro-auricular area if necessary (70). For still larger defects, large cervicopectoral flaps taken from the neck and chest can be valuable, though these may require skin grafting of the donor area. Alternatively, the skin of the neck may be widely undermined and advanced superiorly based on axial vessels posterior to the sternocleidomastoid and in the midline (71). These local flaps provide tissue of ideal texture and color for the cheek location. The use of local tissue also maximizes the natural expressivity of the face. Tissue expansion is often a valuable



FIGURE 6 Design of forehead flap.



FIGURE 7 Postoperative result.

method for increasing the amount of native skin available in the cheek and neck for utilization of these flaps. Multiple expanders can sometimes be used to recruit tissue from a variety of areas. The primary disadvantages of tissue expansion are the multiple stages involved and the creation of more scarring and stiffness within the transferred tissue. This stiffness can limit facial expressivity to some degree. Any of the flaps can also be rotated a second time for a slightly greater degree of advancement when needed. One must be careful with any flap that excessive downward tension is not created, in that this can contribute to extrinsic ectropion and an abnormal facial contour.

If the size of the damaged area precludes the use of local flaps, large full thickness, or thick split thickness skin grafts can provide a reasonable appearance to the badly burned cheek. Grafts rarely appear as natural as local flaps, but the difference in appearance is less apparent if the majority of the remainder of the face is grafted. Distant flaps including free flaps provide another reconstructive option, though the color and texture match are often not ideal. If used they often require multiple revisions to debulk them.

With any of the reconstructive methods, but particularly with grafts and distant flaps, the aesthetic unit of the cheek must be considered in the reconstructive plan. The limitations of these methods in terms of skin color and texture are less apparent if an entire aesthetic unit is involved. In cases where both the lower eyelid and cheek require resurfacing, it is sometimes advantageous to consider both areas as one single aesthetic unit. Similarly, there are occasions where the lip and cheek may benefit from being resurfaced as one unit. When a graft is required to resurface the majority of a cheek, it is sometimes advantageous to sacrifice the remaining normal skin and graft the entire aesthetic unit to maximize uniformity.

Adjunctive techniques can sometimes improve the overall quality of aesthetic results in the cheek. Tattooing can be used to suggest hair follicles in a beard pattern for males with limited areas of hair loss in the hair-bearing portions of the cheek (72).

Perioral Area

In evaluating damaged lips, the normal anatomy must be carefully considered. The lips both have exposed vermillion in addition to skin colored components. The vermillion of the upper lip has lateral segments and a central tubercle. The upper lip skin has a philtral dimple and smooth lateral segments, which tend to overlap the lateral elements of the lower lip. The lower lip has

a sulcus between the lip and chin, and the lip element protrudes to a limited degree. If this sulcus is lost, the chin appears small. In the male, both lips have hair-growing capacity.

Less severe injuries to the lips can be managed expectantly in hopes that functional and aesthetic deformities will become limited with scar maturation. The aggressive use of splinting and physical therapy to limit contractures in the cervical region limits the secondary contribution of cervical contractures to perioral deformities. Methods to accomplish this will be discussed in the section on the neck. Mechanical stretching of the perioral tissues as well as oral splints can limit perioral contractures.

Limited contractures or areas of scar hypertrophy may be improved by simple scar excision. Z-plasties can also be of value in breaking up limited scar contractures. More extensive deformities require aggressive scar release or excision. The lips are areas, like the eyelids, which may require earlier surgical intervention when severe contractures develop. Distortion of the lips can make eating and fluid retention difficult. Lip contractures can also distort speech and limit dental hygiene. In children, they may limit mandibular growth. One must be cognizant of the fact that lip distortion can partially be due to primary lip scarring and partially as a secondary effect of cervical scar contractures. A correct diagnosis of the etiology of any contractures is required to assure appropriate and adequate treatment. Like the eyelids, early contracture release may be indicated, with the realization that a later more definitive secondary procedure may be necessary after scars have matured.

Lower lip release is usually performed first because contractures of this area are disabling and can contribute to extrinsic contractures of the upper lip. Release is typically carried out at the vermilion scar juncture with care not to damage the underlying orbicularis muscle. Care must be used in any excision to maintain the chin prominence to the best degree possible. In addition, the chin-lip sulcus should be preserved if possible. Tissue deficiency is then corrected with split or full thickness skin grafts. Sometimes a chin implant can aid in the maintenance of chin projection.

Ectropion of the upper lip can be released by incising along both nasolabial folds as well as at the base of the nose. This technique permits the upper lip to fall back into its native position. Extensively damaged upper lip skin should be excised and resurfaced as an aesthetic unit. It should be kept in mind that some of the scarred tissue may have value in reconstructing the alar base or columella in the nasal region. These areas are less visible, and augmentation with scarred tissue may provide contour improvements that are useful.

The aesthetic units of the lips are carefully considered in planning grafting. The interdigitation of lip and cheek units should be made a zig-zag line when possible to limit contracture. In the upper lip, it is often difficult to maintain a normal philtral dimple when the entire lip is grafted. It can sometimes be preserved as a separate aesthetic unit, while grafting the lateral upper lip elements. It is important to reconstruct the lateral elements in a like manner to maintain natural lip symmetry. Full thickness grafts or thick split thickness grafts are optimally used and a supraclavicular donor site is preferred. Other donor site options include the retroauricular or submental areas. Expansion of the donor site can augment the amount of skin available from a particular location and is sometimes of value. Templates are sometimes used to assure precision in graft sizing. If the philtrum lacks definition, composite grafts from the fossa triangularis or concha of the ear including cartilage and skin can sometimes be useful in regenerating a more natural contour. Narrower philtral grafts generally are aesthetically superior to wide ones. For limited defects in the hair-bearing areas in males, scalp grafts are sometimes valuable.

Flaps sometimes have utility in lip reconstruction. If adjacent cheek tissue is not damaged, nasolabial flaps and other flaps from the cheek can be used for reconstruction of more limited defects. In the male patient, flaps are sometimes used to transfer hair-bearing tissue to the lip area. A long flap based on the temporal artery can be tunneled under the cheek to the upper lip to recreate a mustache (73). Alternatively, a free tissue transfer of occipital hair-bearing tissue can be utilized (74). A bipedicle flap from the submental area has also been used for reconstruction of a hair-bearing mustache, often with primary closure of the donor area. A bipediced scalp flap based on both superficial temporal arteries can also be used to transfer hair-bearing tissue to the mustache or beard area as well (75). If any donor area is deficient, preliminary tissue expansion can sometimes be helpful.

Small flaps of vermillion can often be useful to create a more normal contour in this area. Mucosal advancement flaps, Z-plasties or V-Y plasties can often be valuable. For more severe defects, tongue flaps can effectively replace vermillion mucosa. Creation of symmetry and avoidance of notching in the vermillion border should be important considerations in any vermillion reconstruction.

Oral commissure burns are typically seen in children who chew on electrical cords. The oral commissure can also be damaged by any severe burn in the perioral area. The injury will limit the size of the mouth and diminish the normal expressivity of the perioral area during facial animation. Oral splinting is typically an important first mechanism to minimize scar contracture in this area.

A variety of reconstructive methods exist for commisuroplasty, which correctly suggests that none are universally successful (Figs. 8–10). The likelihood of success is optimized if the procedure is carried out after scars have matured. Some prefer a simple wedge-shaped scar excision with mucosal advancement. The Gillies-Millard commissure repair is also often used (76). With any method, overcorrection is generally preferred in that some recurrence of the contracture will inevitably occur postoperatively. Postoperative splinting may limit this to some degree.

Neck

The neck is normally a concave and highly mobile structure. As mentioned previously maintenance of the normal contour can be optimized by exercises and the use of neck collars in the early period after a burn injury. Cervical flexion contractures are often difficult to avoid however in severe burns of the neck in spite of preventive measures. These contractures produce problems both because of direct limitations in the cervical region and secondarily as a result of traction on distant structures such as the eyelids and lips. Excessive traction on the lip can result in drooling and dental problems when contractures are extreme. Severe cervical contractures can also produce local pain, airway constriction, and compensatory postural abnormalities. Extrinsic contracture of the lower face will create a significant amount of mechanical disability. In addition, cervical contractures can create significant aesthetic deformities including obliteration of the cervicomentale angle and oral exposure (Figs. 11 and 12). Because of these problems, severe deformities may require early treatment. As with eyelids and the perioral area, secondary procedures after scars mature are not uncommon.

Simpler deformities such as vertical scar bands can be released with single or multiple Z-plasties. Occasionally, linear transverse scars are amenable to scar excision and advancement of adjacent uninjured neck skin. For more extensive scars, generous scar releases that extend transversely across the entire neck must be utilized. They should generally extend past the scarred areas on either side of the neck to provide complete contracture release. Unless a particularly tight scar mandates release in a specific location, scar release is often best achieved at the level of the hyoid bone to emphasize the cervicomentale angle. Secondary releases at the clavicular level can also be used to further facilitate neck extension.

Scar releases must often extend through the platysma as well as the anterior cervical musculature to completely release a contracture. Incisions should not be made excessively deep



FIGURE 8 Electrical burn of oral commissure.



FIGURE 9 Scar contracture resulting from secondary healing.

though in that irregularities can be created in the cervical contour laterally. At the end of the releasing incision, V-shaped extensions are often used to allow for a more complete release. Thick plates of scar must often be completely excised as opposed to incised to allow complete release of the scar.

Optimally, a full thickness skin graft is used when possible to limit secondary contracture and recurrence of scar deformity, but the size of graft required frequently makes the use of a full thickness graft impractical. Thick split thickness grafts are therefore used more commonly. Excision of submandibular and submental fat and sometimes a platysmal plication prior to graft application can highlight normal neck contour in the cervicomental area. A bolster dressing is commonly tied over the graft to provide immobilization and compression during the initial phase of graft healing. If the dressing does not adequately immobilize the graft, a splint can be used as well. Minimization of neck motion with swallowing may require a liquid diet. Strict bed rest can also aid in minimizing movement and maximizing graft take. After the bolster dressing is taken down, usually five to seven days after graft placement, the area must be splinted in extension for at least six months to minimize the risk of recurrent contracture.

Recently synthetic dermal elements provided by Integra or Alloderm have been utilized with thinner grafts in hopes of providing greater resistance to secondary contracture. Others prefer to use large local flaps or even free flaps to provide greater contracture resistance. Local flaps can often be designed from unburned areas on the lateral neck, upper chest, shoulders, and upper back. Local flaps can sometimes be augmented by tissue expansion. When tissue expanders are utilized, they are best placed in the lateral neck or infraclavicular region, if these tissues are uninjured. Free flaps have also been utilized, though none of the common free flaps are large enough to completely resurface an extended neck. All flaps frequently require



FIGURE 10 Result of commissuroplasty.

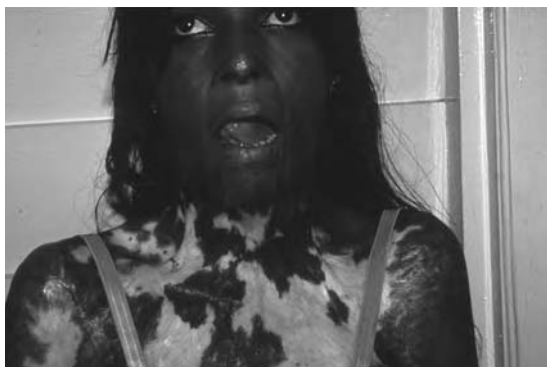


FIGURE 11 Severe cervical contracture—anterior view.

secondary thinning in that they are generally too bulky and do not provide a natural appearing neck contour. These problems can be exacerbated if the patient gains weight subsequent to the procedure.

In orienting grafts or flaps in the cervical region, vertical scars should be avoided to limit the opportunities for recurrent contracture. If a combination of flaps and grafts is used, the flap should generally be placed in the more visible anterior neck.

Ear

Burns of the ear are relatively common due to ear prominence, though they are generally associated with burns to other parts of the face. Partial thickness burn injuries that heal secondarily rarely require any additional reconstruction. Occasionally, a keloid or hypertrophic scar will develop and require treatment. Contracted scars can frequently be managed with Z-plasties or local flaps. Deeper burns can produce areas of tissue loss. On occasion, the injury is limited to skin on one surface, which can be resurfaced by grafting. Even if a portion of cartilage is lost, grafts can be placed on the postauricular skin. Grafts can even be placed in the region of the helix where they can provide a relatively natural appearance.

In some severe burn injuries, portions of the ear can be completely destroyed by the initial burn injury. In other cases, exposed cartilage may initially appear viable, but then subsequently desiccate and escharify. In either case, the nonviable area will demarcate and separate leaving a vascularized rim of tissue that will heal or can be closed. Efforts have been made to cover exposed cartilage with vascularized tissue before it desiccates to optimize tissue salvage with some success. This can be accomplished by mobilization of auricular tissue in a subperichondral plane or distant flaps.

Auricular tissue can also be lost secondarily due to suppurative chondritis. As mentioned previously, the incidence of these infections has diminished with the use of topical Sulfamylon



FIGURE 12 Severe cervical contracture—lateral view.

or iontophoresis of antibiotic containing solutions beginning soon after the injury. If suppurative chondritis develops, it usually does so three to five weeks after the burn injury. *Pseudomonas* is involved in 95% of cases and *Staphylococcus* in 55% (77). It presents with dull localized pain that increases in intensity within hours. The area becomes warm, erythematous, swollen, and tender. A fluctuant area is sometimes noted which can be drained if it does not drain spontaneously. Though several approaches have been taken to the treatment of suppurative chondritis, most successful methods include appropriate intravenous antibiotics and aggressive debridement of all nonviable cartilage with subsequent topical antibacterial treatment.

After wounds have healed, a reconstructive plan can be developed. Individuals with longer hair may choose not to reconstruct an auricular defect, but simply to conceal it. Helical defects, which are small, are best addressed with Antia-Buch advancement flaps (78). Composite grafts from the opposite ear can also be utilized to reconstruct limited helical and auricular defects as well. More extensive defects of the helical rim can be reconstructed using a tubed flap from the postauricular area that is elevated initially as a bipedicle flap and is subsequently advanced to the ear in stages. Larger defects involving more than the helical rim can be addressed with a conchal transposition flap. This involves elevating a composite flap of skin and cartilage from the concha with its pedicle at the crus helix and transferring this tissue to the upper third of the burned ear (79). The resulting conchal defect is grafted. Localized defects of the lobule can also be reconstructed with local flaps using adjacent tissue.

Some patients may be candidates for total or near total auricular reconstruction using a costal cartilaginous framework. The framework is ideally covered with mastoid skin, though temporoparietal fascia covered by a graft can be used if the mastoid skin is too badly damaged (80). Alternatively, somewhat damaged skin can be expanded and used to cover a cartilaginous framework if it has some degree of pliability. The quality of these reconstructions is primarily dependent on the framework, which needs to highlight the cartilaginous contours desired. Alloplastic frameworks should generally be avoided.

An alternative to reconstruction is the use of a prosthetic device. These can be used temporarily prior to a surgical reconstruction or permanently. Osteointegrated auricular prostheses can provide a more anatomic reconstruction than virtually any surgical method (82).

PSYCHOLOGICAL ISSUES

Severe facial burn injuries can cause significant distortion in an individual's body image. This is particularly true in children. Children develop an awareness of body image at the age of three to four. Facial scars lead to more difficulty psychologically than scars to other parts of the body. Children who grow up with severely scarred faces are more likely to lack self-confidence, have feelings of self-guilt, and depression and to be slow to mature. Regardless of cognitive ability, severely burned children are likely to have difficulties in school.

Adults are not immune to feelings of isolation in our image conscious society after severe facial burns. Women are particularly prone to post-traumatic stress disorder after any burn injury (82). A review of the life experiences of severely burned soldiers from World War II emphasizes the differences in how individuals deal with severe facial scarring (83). Some become hermits and isolate themselves from society, while others cope and adjust to their altered body image. Even lesser burns can cause significant changes in social functioning in some people. A follow-up study of 28 facially burned patients demonstrated that in the year of injury, the majority had increased alcohol consumption and fewer social activities and 11 had different partners (84).

Significant facial deformities often create difficulties in forming relationships and frequently limit an individual's ability to be a functional member of society (85). These difficulties with social interactions derive at least in part from the individual's diminished self-esteem. Significantly disfigured individuals commonly demonstrate increased anxiety levels and tend to avoid social situations where their disfigurement will be apparent.

In addition to the injured individual's limited self-confidence, society tends to discriminate against individuals with disfigurement which contributes further to an individual's social isolation. The reasons for this discrimination may derive partly from an unconscious sense that the disfigurement may be deserved or because of a sense that an individual's societal standing

is related to appearance. It also can derive because of concern about whether the condition is contagious and uncertainty about how to interact with a disfigured individual. Some of these reasons can be countered by teaching social skills that encourage the individual to be proactive in educating individuals with whom they interact about the nature of the problem.

The individual qualities that allow some to cope well with severe facial deformities have not been clearly identified. Family support is a key factor in facilitating coping with severe disfigurement. There has been an increased emphasis on psychological counseling and support groups, and there are currently organizations such as Changing Faces and the Phoenix Society, which are devoted exclusively to improving the social functioning of facially altered individuals. Outcome studies for different types of intervention have not been carried out to date, however, and the best methods for facilitating social adjustment have not been identified (86). An individual's reactions to his or her injury changes over time and long-term evaluations have not been published.

CONCLUSION

The management of facial burns requires precise early treatment of the injury, aggressive early treatment of scar contractures causing functional difficulties, and careful staged planning of the definitive reconstruction of damaged structures. The debate on the timing of early surgical interventions for severe burns and the value of some adjunctive modalities will persist, but the overall management plan must be crafted with the goal of optimizing aesthetic and functional outcomes.

In spite of our best efforts, facial burn management is often limited by unaesthetic final results. The often humbling results achieved after severe facial injuries provide a continual challenge encouraging the development of newer and better surgical and nonsurgical treatment modalities.

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12 Cheek Reconstruction

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INTRODUCTION

The cheeks, probably more than any other area of the face, show prominent variation from person to person. As individual ages, the cheek tissue elongates, and changes in color and shape. As a by-product of this elongation process, however, more skin is available for cheek reconstructive procedures particularly in more aged individuals.

Basic principles for cheek reconstruction should be to attempt to keep the final scar as short as possible and the long axis oriented in the direction of natural or resting skin tension lines. Small cheek defects created by elliptical excision may be closed primarily. Larger defects can be resurfaced with either skin grafts or preferably, local flaps. The full-thickness skin graft is generally considered an “alternative” option in the cheek region, but does have the advantages of simplicity and absence of conspicuous facial, donor scars. In part, due to the fact that a skin graft is ischemic on transfer, the ultimate color, texture, pigmentation, contour, contracture, and perimeter scarring are less predictable. Because color- and tissue-thickness mismatches regularly occur with skin grafts, local flaps are more attractive as reconstructive alternatives.

Although local flaps have the advantage of similar color, texture, and tissue thickness when compared to defects in the same region, they also have the drawback of more local scarring with their creation and movement to fill the defect. Some guiding principles exist, however, such as preserving aesthetic units of the cheek, by placing incision lines in regions of normal “interface” (e.g., preauricular creases, nasolabial fold, zygomatic arch, infraorbital rim, and below the inferior mandible border) less conspicuous scarring is seen.

Because the location and size of the defects are so varied, multiple flap designs have been developed. The categories for superficial skin flaps of the face are random (transposition, advancement, rotation, interpolation), axial (cervicofacial), and round block (“purse string”) flaps.

Some of these flaps are listed as follows:

I. Random flaps

1. Transposition: flap tissue is transferred over intact skin.
 - a. Rhomboid flap and variations rhombic and
 - rhomboid Schwenklappen plasty
 - rhomboid-to-W flap
 - double-Z rhomboid plasty
 - b. Nasolabial flap
 - c. Lateral cheek and posterior auricular transposition flap
 - d. Cervicofacial skin flap to the cheek
 - e. Z-plasty
 - f. Bilobed flap
 - g. Trilobed flap
2. Advancement: advancement flaps are used primarily for broadly based defects.
 - a. V-Y advancement skin flap
 - b. Subcutaneous pedicle flaps
 - c. Kite flap
 - d. Burrow’s cheek advancement flap
3. Rotation: flaps used primarily for triangular-shaped defects.
 - a. Cervical rotation skin flap
 - b. Slide swing skin flap
 - c. Esser cheek rotation (medial cheek defects)

4. Interpolation: uses subcutaneous vascular pedicle to carry skin.
 - a. Triangular and Hachet subcutaneous pedicle skin flap.
- II. Axial flaps: defined larger ("named" blood vessel source of vascularity)
 - a. Superficial temporal artery (forehead)
 - b. Scalp flaps PARAS (postauricular, retroauricular scalp flap) Washio
 - c. Posterior cervical flap
- III. Pedicled musculocutaneous flaps
 - a. Platysma
 - b. Sternocleidomastoid
 - c. Pectoralis major
 - d. Latissimus dorsi
- IV. Microvascular transferred free flaps
 - a. Rectus abdominis
 - b. Latissimus dorsi

Free flaps are most commonly indicated for extended through and through defects of the cheek.

CONTOUR DEFECTS

For contour defects of the cheek like Romberg's disease, scleroderma, facial lipodystrophy, or soft-tissue trauma management, other treatment options are available:

1. Dermal grafts
2. Dermis – fat grafts
3. Autogenous fat grafts
4. Local deepithelialized flaps
5. Free tissue transfer

Injectables, such as collagen and Restylane, can improve contour, but generally resorb within six months and must be repeated in order to have persistent improvement. In our experience, there are two commonly used and versatile techniques that can be used for cheek reconstruction with excellent results: the cervicofacial flap and the round block purse-string suture method. These two techniques will be described in detail.

Cervicofacial Flap

The cervicofacial flap was first described by Beare (1) for obtaining skin cover following orbital exenteration. Subsequently, it has been used for a wide variety of reconstructive purposes in the orbital, lower lid, and upper cheek area. The pedicle may be located in either the preauricular or nasolabial area.

The cervicofacial flap uses the skin laxity in the neck to fill a defect in the upper cheek or orbital regions. It has many advantages, which includes the ease of dissection, safety, and reliability, and in most cases, the absence has a significant secondary donor defect.

The final cosmetic appearance is usually excellent, because the scars are aligned in the resting skin tension lines of the face, and the color match is good (2) (Fig. 1). There are two types of cervicofacial flaps: laterally and medially based cervicofacial flaps.

Laterally Based Cervicofacial Flap

Anatomy and Blood Supply

The anatomy of the cutaneous vascular system assumes particular importance in the design of successful tissue transfer. Most skin and subcutaneous tissue in the face are supplied by branches of the external carotid artery system. With the laterally based cervicofacial flap, two main vascular systems are left intact; first, the transverse facial artery, a horizontal branch of the superficial temporal artery as it crosses the zygomatic arch, which contributes vascular supply to the superior aspect of the flap. Second, the major vascular supply of the flap is from branches of the main trunk of the facial artery, as it enters the face by crossing over the inferior border of the mandible. This landmark can easily be palpated or defined by doppler (3).

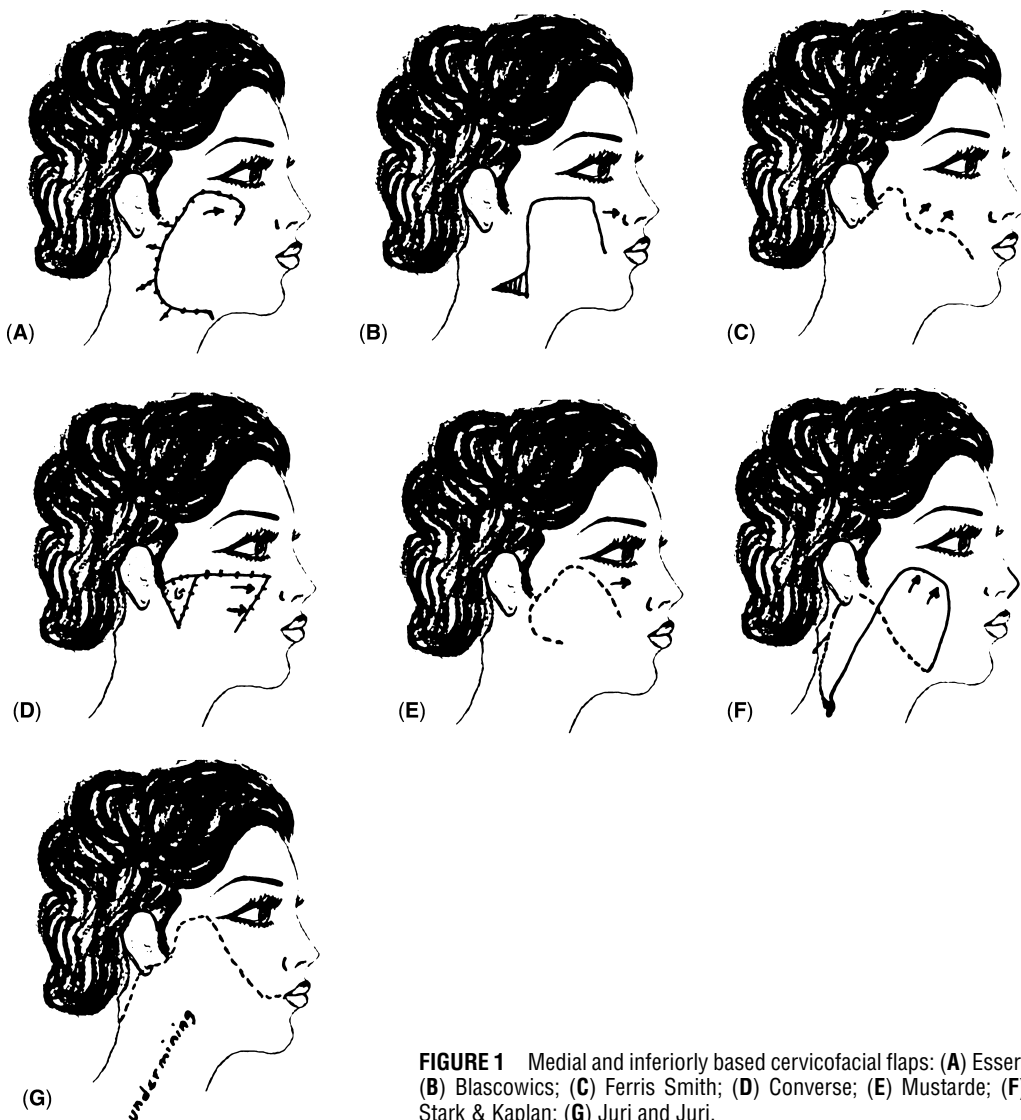


FIGURE 1 Medial and inferiorly based cervicofacial flaps: (A) Esser; (B) Blascowics; (C) Ferris Smith; (D) Converse; (E) Mustarde; (F) Stark & Kaplan; (G) Juri and Juri.

Posterolateral and inferiorly based flaps, as described by Skoog (4) and Hamra(5–7), have circulation which is considerably more robust in most patients because of the intact contributions of the transverse facial artery superiorly and the main facial artery inferiorly (Fig. 2).

The detractors of standard, anteriorly based cervicofacial advancement flaps, are prominent scarring, flap ischemia, eyelid ectropion, inadequate or excessive contour restoration, dog-ear deformity at flap borders. For lesions in the anterior cheek, ipsilateral sidewall of the nose, and lower medial periorbital region, an inferiorly and laterally based cervicofacial advancement flap has more reliable blood supply, a design capable of more flexibility, and most important, it brings the incision line for these anterior cheek lesions to the side wall of the nose. Small defects (<4 cm in diameter) can be reconstructed by a flap developed only to the level of the ipsilateral oral commissure (Fig. 3). This limited dissection reduces the length of the scar. For larger defects (more than 4 cm in diameter), the incision is extended down past the nasolabial fold around the modiolus, then inferior to the oral commissure, where it parallels the aesthetic subunit between the lip and the chin. The incision curves around the chin subunit into the submental region, joining the chin crease, where the submental incision normally is made in rhytidectomy, for cervical dissection. The incision then is brought posteriorly and laterally toward the ipsilateral cheek, so that the point of the submental “V”

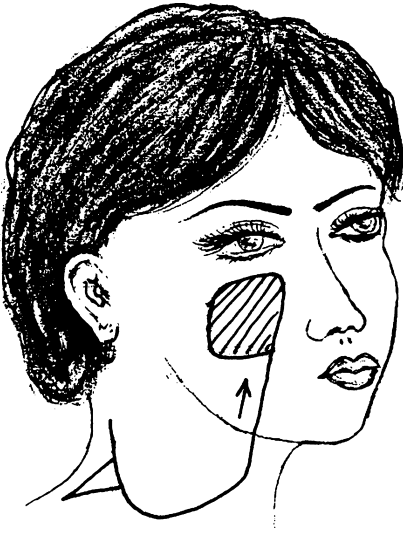


FIGURE 2 Laterally based cervicofacial flap.

produced, can be rotated and advanced to the junction between the inferior labial and chin units. In flap transfer, the V marks the sublabial-chin unit junction, which is rotated superiorly to develop the border between the nose, cheek, and upper lip subunits. The point previously at the oral commissure is transposed toward the medial canthus, along the sidewall of the nose, and then inset above the alae. The flap can easily be suspended on the adjacent periosteum, medial to the medial canthal area. This internal suspension reduces the traction on the ipsilateral lower eyelid minimizing the chance of ectropion postoperatively. Because the skin and fat are of various thicknesses along the length of the flap, the thickness of the fat is typically altered to prevent contour irregularities.



FIGURE 3 Laterally based cervicofacial flap for cheek and commissure reconstruction in a 17-year-old boy with shell injury of the cheek and commissure. (A,C) Preoperative photos; (B,D) immediate postoperative photos.

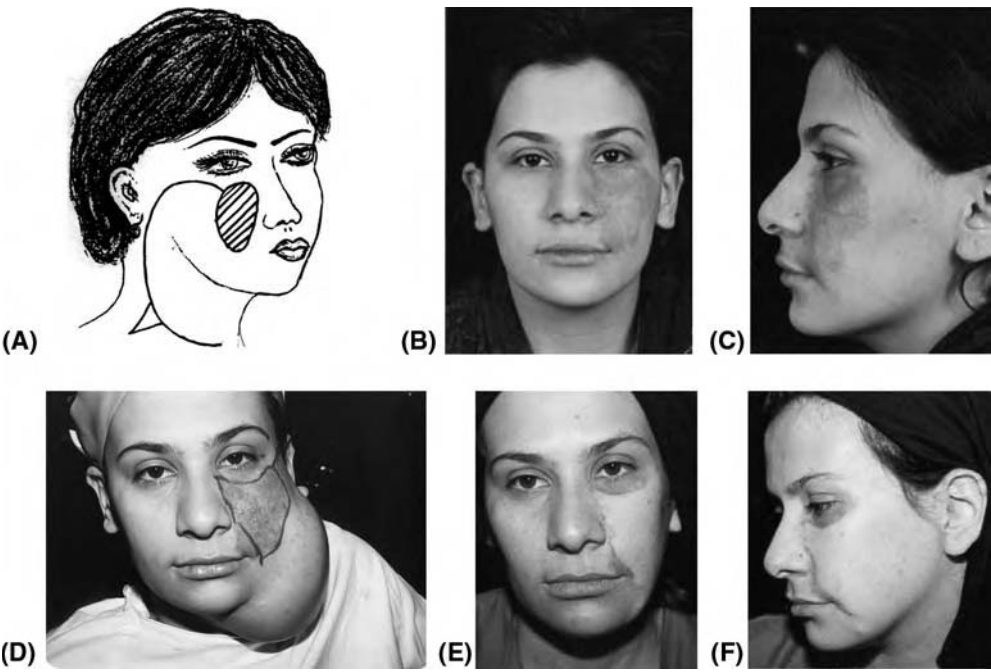


FIGURE 4 Medially based cervicofacial flap. (A) Flap design; (B,C) a young woman with a hemangioma in left cheek; (D) patient with a tissue expander; (E,F) final result after excision and reconstruction with medially based cervicofacial flap.

The flap is dissected laterally to an imaginary vertical line paralleling the lateral canthus. The dissection always remains superficial to the superficial muscular aponeurotic system (SMAS). Along the border of the midmandible, the branches of the facial artery should be respected and preserved. After the flap has been rotated superiorly and anchored to the periosteum, the surgeon may be tempted to excise apparent excess eyelid skin. Ectropion can be minimized if excess tissue deliberately is left in the superior border of the flap adjacent to the eyelid (8–10). Cheek skin must not be used to replace the eyelid skin unit because it does not



FIGURE 5 Bilateral reconstruction of burned cheek with bilateral medially based cervicofacial flaps. (A-C) Before operation; (D-G) final results.



FIGURE 6 Reconstruction of cheek and lateral side of the nose in a man with SCC of right cheek and sidewall of the nose. (A) Flap before inset; (B) flap inset; (C) immediate result; (D) final result.

match in thickness. Revision can be performed at a secondary stage only after it has become clear that excess tissue exists (after several weeks have elapsed). Leaving the excess tissue often yields an eyelid that is initially full, but ordinarily either thins out or may be surgically defatted secondarily.

To prevent permanent facial nerve injury, the dissection in the areas between the levator labii superioris and zygomatic major muscles must remain in the plane anterior to SMAS.



FIGURE 7 Reconstruction of cheek and half of the upper lip with medially based cervicofacial flap. (A) Preoperative view; (B) immediate postoperative result.

Medially Based Cervicofacial Flap

Large, lateral, facial defects remain a reconstructive challenge to the plastic surgeon. Traditional methods of dealing with these defects, including split thickness skin graft, local flaps, regional flaps such as the deltopectoral flaps, as well as musculocutaneous flaps, all have their limitations and are far from ideal. The medially based cervicofacial flap for large lateral facial defects has emerged as a superior reconstruction option in many cases (Figs. 4 and 5).

The advantage is one can reconstruct the whole esthetic unit of cheek (to include the sidewall of the nose), unilaterally and bilaterally, with such flaps (Figs. 6 and 7).

Technique

The flap incision is designed in a wide curvilinear line, sweeping in a convex form from the lobule of the ear to the base of the neck. With smaller facial defects, the inferior extension of the incision line for the flap may be limited. However, with larger defects (>4 cm diameter), the incision should be taken down over the clavicle onto the anterior chest wall becoming a cervicopectoral flap (Fig. 8).

The neck flap is pedicled on the vessels of the upper anterior aspect of the chest and the medial aspect of the neck. The cervicopectoral skin flap is analogous to the deltopectoral flap (Bakamjian). The blood supply consists of the internal thoracic artery perforators, which arterialize the chest portion of the flap. The attached neck skin was originally considered to be a randomly vascularized portion of the flap; however, it has been so robust and reliable, that it very likely receives nourishment from the platysma musculocutaneous perforators, too.

The placement of the incision depends on the site of the defects and whether any additional surgery is required. In cases where there is clinical involvement of neck nodes or a high probability of occult metastases, a neck dissection can readily be performed through this incision, if curved posteriorly to a point less than 2 cm posterior to the anterior border of the trapezius. The more posteriorly placed incision is cosmetically more acceptable. Care must be taken not to injure the mandibular branch of the facial, and the accessory, nerves in the course of flap elevation.

Once elevated, the flap is rotated into the defect. The donor site normally can be closed primarily, except in cases where a very large defect is evident. In these situations, a split-thickness skin graft may be applied and usually remains hidden well below the collar line. It may also be serially excised at a later date, if required for cosmetic concerns. The operative site is drained with a suction drain. In the postoperative period, care must be taken not to apply pressure to the region of the flap's base. The patient is nursed with the head slightly elevated and flexed, if tension is a concern. The head may also be rotated to the side ipsilateral to the defect side and, if required, fixed with a temporary traction suture.

Complications are uncommon, but may include margin necrosis and ectropion of the lower lid. Reducing tension by appropriate dissection, and overcorrection of lower lid height with superior fixation will lessen the occurrence of these problems.

ROUND BLOCK "PURSE-STRING" SUTURE METHOD

Despite the use of meticulous wound closure techniques, virtually all plastic surgeons have, sometimes, unexpectedly, faced the problem of prominent scarring in the cheek. Accepting this as an inevitable risk of any surgical incision, the shorter the scar, the better the outcome is likely to be. The purse string technique is designed to provide this shortened scar length regularly.

Technique

After removal of a skin lesion, a round or ovoid defect is normally visible. In general, minimal or no undermining of the wound edge was performed by Hirshowitz et al (11) in an effort to maximize vascularity. A nylon or prolene suture, as thick as possible (minimum 2-0), was passed intradermally by Benelli (12) for his "round block" mammoplasty in a similar thought process. The wound margins are progressively approximated by tightening the suture. The final closure often is completed using a few external stitches to avoid blood and/or serum leakage. The external stitches are removed in five to eight days to avoid stitch-related scars. The larger gauge, "round block" suture, however, is to be left for a minimum of four weeks (12).

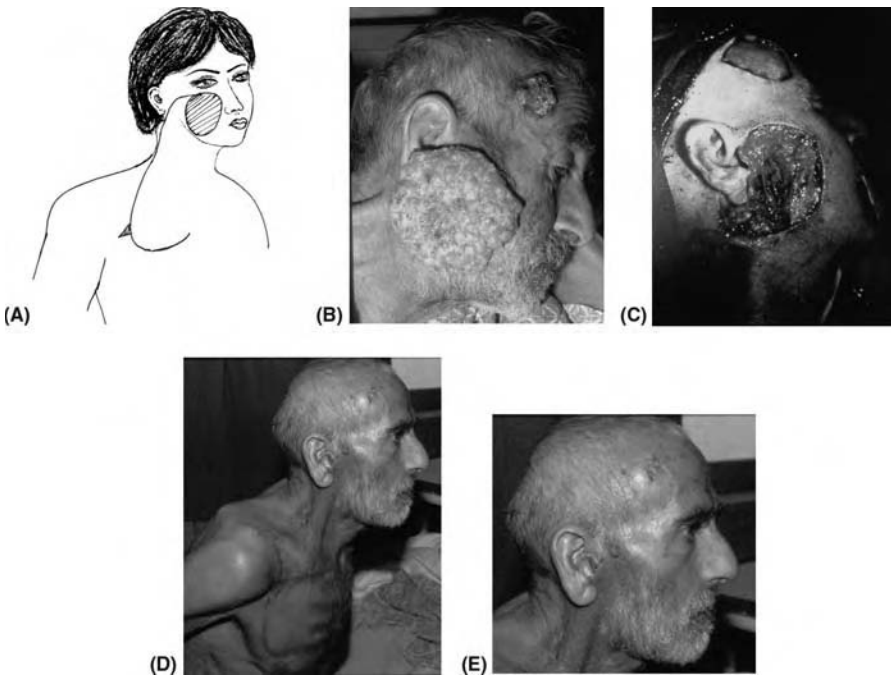


FIGURE 8 Reconstruction of cheek in a man with large SCC of right cheek with cervicopectoral flap: (A) flap design; (B) the tumor; (C) the defect after resection of the tumor; (D,E) final result after reconstruction with cervicopectoral flap. Abbreviation: SCC, squamous cell carcinoma.

In the immediate postoperative period, the suture is surrounded by a large number of concentric redundant skin folds, accompanied by considerable distortions of the nearby structures. Both distortions improve spontaneously over a period of two to three weeks and often are relatively insignificant by the time the encircling suture is removed. The scars, which, at closure, initially are very limited and almost circular (except for the larger excisions), are subsequently excised as an ellipse, with the long axis of the ellipse oriented along the skin tension lines, three to six months later. Reductions in scar length may be 30% to 50% over what could be achieved with direct excision and closure alone.

The final scar is always typically shorter than the original defect length, and usually quite acceptable. Moderate widening has occurred when we used larger suture (1-0 or more), which was left longer (six weeks or more) (Figs. 9 and 10).

Advantages of the “round block” purse-string suture are as follows:

1. It is a simple, inexpensive, and rapid technique for closing wounds by stimulating expansion of the surrounding skin.
2. It can minimize scarring; the final scars are shorter than the original defect and usually of very good quality.
3. It allows a very useful temporary closure that stretches the surrounding skin while waiting for the definitive histologic report. If this method is not chosen as a definitive closure, later repair with local flaps or skin grafts may be facilitated.
4. It never compromises the final result, even in cases of dehiscence.

COMPLICATIONS

Complications of the “purse-string” closure approach include dehiscence (approximately 10%) between one and two weeks. Almost all these wounds are closed subsequently using interrupted sutures with less tension, taking advantage of the “expansion” of the surrounding skin in the interim similar to presuturing techniques (13).

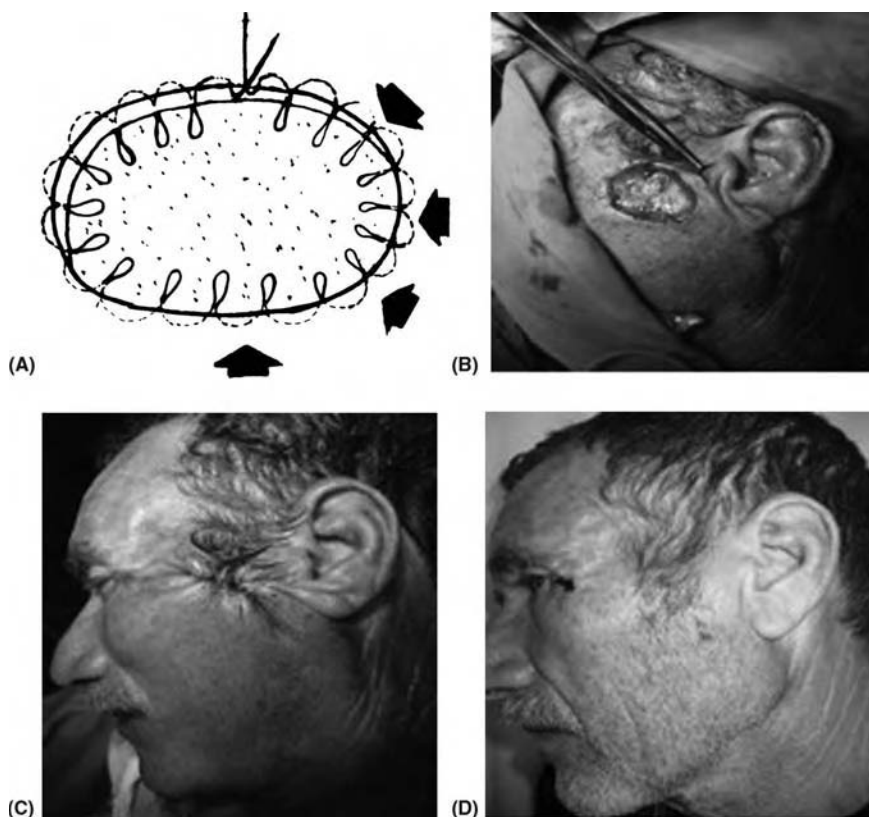


FIGURE 9 (A) The round block technique. (B) Before tightening of suture; (C) immediate result; (D) final result several weeks later.

Hypertrophic scars have occurred in 9% of patients at the time of suture removal, which usually resolves spontaneously in 4 to 12 months.

The main disadvantage is the acceptability of the skin distortion by patients in the short term. They need to be carefully prepared for both the initial distortion of the soft tissue and for the long time the pressure releasing “purse string” suture that has to be retained. The request for a too early suture removal (less than four weeks) must be considered a complication of this method because, in such cases, there was always significant scar stretching and an unacceptable cosmetic result. This approach also requires two surgical steps, that is an additional surgical procedure, when compared with “traditional” single staged excision and reconstruction techniques.

CONCLUSION

The “round block” purse-string suture can produce reliable and often very satisfactory results, provided some basic principles and technical modifications are respected.

These guidelines are as follows:

1. Minimal or no undermining of the margins.
2. Use of nonabsorbable sutures of sufficient caliber to avoid cutting through the dermis (2-0 gauge).
3. Retention of the suture for at least four to six weeks.
4. Disregard for the temporary distortion of the surrounding skin.
5. Comprehensive discussion of the proposed procedure with the patient who needs to be carefully prepared for both the gross initial distortion and the length of time the suture needs to be retained (14).

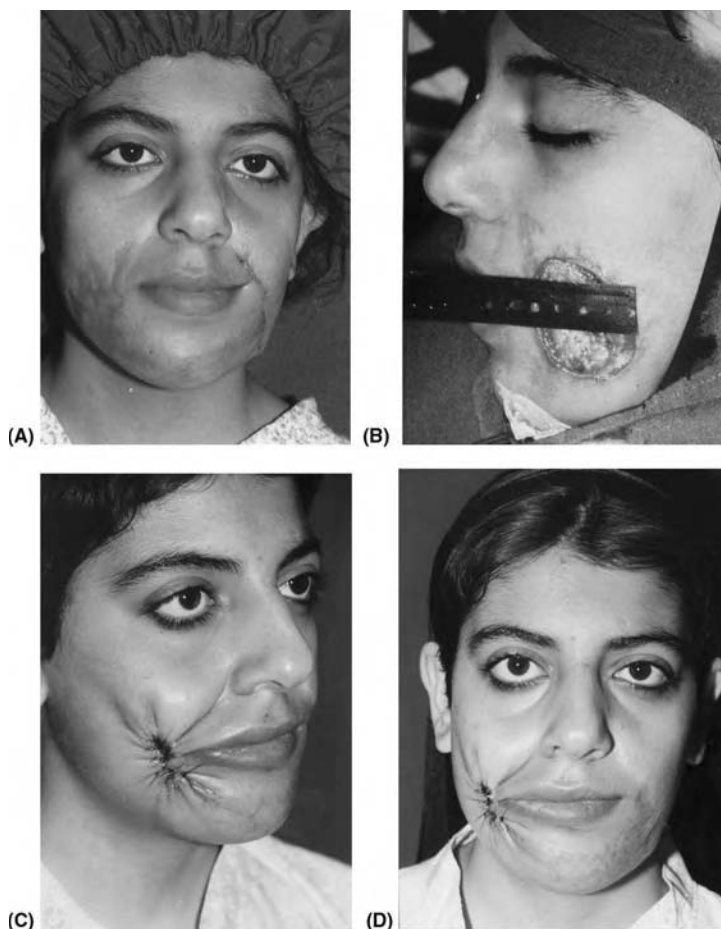


FIGURE 10 The round block technique for reconstruction of a burn scar. (A) Burn scar in the right cheek area; (B) scar was excised; (C,D) immediate result.

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13 | Traumatic Tattoo

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INTRODUCTION

Traumatic tattoo is the unintentional deposition of inert pigmented substances within the skin. Compared to professional tattooing, important variations exist with regards to pigment composition and placement. Traumatic tattoos typically display a heterogeneous distribution of particles throughout the depth of the skin and subcutaneous tissues. The size and nature of the embedded pigments also differ within and among traumatic tattoos. These factors, along with the nature of the inciting injury, determine the appearance of the tattoo and guide therapeutic decisions (Fig. 1). Due to the varying quality and thickness of skin in the craniofacial region, and the high visibility of scars or dyspigmentation in this area, traumatic tattoos of the head and neck require careful, well-planned management to obtain a satisfactory long-term cosmetic result.

MECHANISM

The common mechanisms of injury that produce traumatic tattoos are abrasion, explosion, and puncture (Table 1). Each etiology is associated with a characteristic range of preceding events and deposited pigmenting substances. Abrasions are the most common cause of traumatic tattooing and typically result from oblique forcible contact with asphalt, gravel, or soil. Friction generated between the skin and the contact surface produces abrasive injury with simultaneous impregnation of the tissue with foreign particulate matter. Patients typically fall while running or riding a vehicle such as a bicycle, skateboard, or motorcycle. Persons ejected from, or struck by, automobiles also commonly present with a component of abrasive injury. The exposed areas of the body are more likely to be affected such as the forehead, nose, and face. Lacerations and avulsions may accompany the abrasive injury. The implanted pigmented substances can range from mineral to vegetable matter but generally are carbon based. This produces an irregular pattern of blue to black spots, depending on the depth of the particle within the dermis.

Tattoos resulting from explosive injury can be subdivided into civilian, military, and industrial. Civilian explosive tattooing occurs from ignited gunpowder used in firearms, fireworks, or dynamite. Black powder, assorted casing debris, and soil constituents are the most commonly embedded particles. Military explosive wounds can have a wide range of implanted foreign materials included in the constellation of injury. Debris and shrapnel consist of sand, soil, glass, metal, or wood. Industrial explosions are less common but can deposit a wide variety of particles such as petroleum-based compounds, chemicals, and metals. Tattooing from explosive injuries most commonly affects the face (1).

The majority of puncture wound tattoos involve pencils and pens. The resultant discolorations are typically black but can exhibit the reds, greens, and blues of pen ink. The lesion is normally superficial, solitary, and almost exclusively found in school-aged children.

Other less common methods of traumatic tattooing include iatrogenic deposition of superficially placed pigmented suture (2), iron residues from battery powered earrings (3), and various fabric pigment depositions associated with burn injuries (4).

Due to the variety of pigment depth and composition, traumatic tattoos have been likened to amateur tattoos with respect to treatment. However, the management options for traumatic tattoo have changed greatly over the last 30 years, most notably with the advent of laser technology. The treating physician should be familiar with the common historical and modern therapeutic options due to the breadth of clinical scenarios in which traumatic tattooing presents.

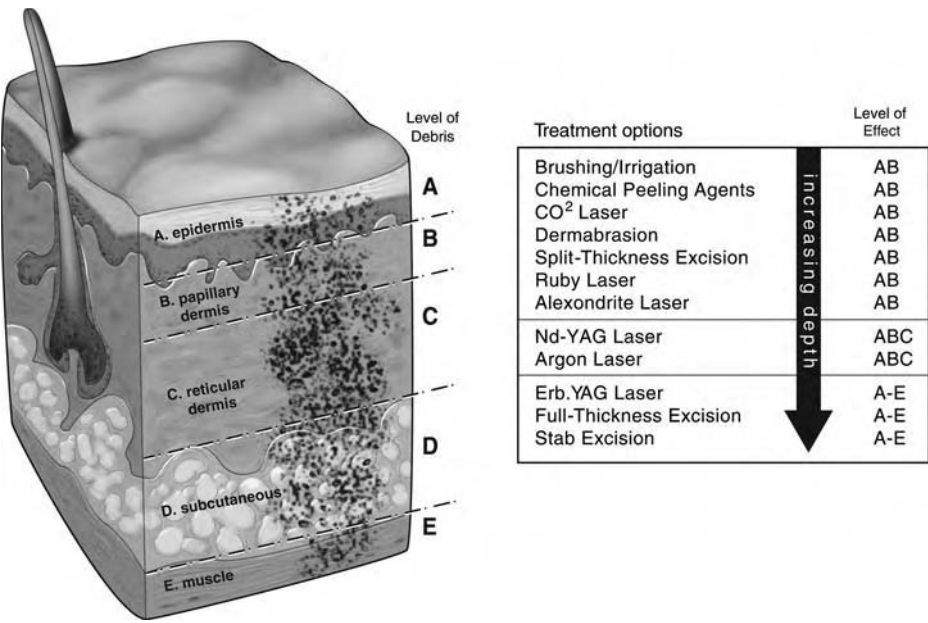


FIGURE 1 Treatment options by pigment depth.

PATHOPHYSIOLOGY

After the acute deposition of pigmented particles in the skin associated with trauma, the initial reaction is that of inflammation and exudation. Macrophages attempt to phagositize and export the foreign bodies out of the zone of injury. Exudation allows for debris to be mobilized to the wound surface for removal as slough. After several weeks, the dermal–epidermal junction is reconstituted and the macrophage population normalizes. This inhibits further migration of pigment to the surface thereby entrapping the particles within the substance of the skin and subcutaneous tissues. Smaller particles become incorporated into the cytoplasm and phagosomes of constituent cells, mainly fibroblasts but also local macrophages and keratinocytes. Larger particles are encased in fibrotic tissue (5,6). Most traumatic tattoos will show mild improvement over the first year as the smaller pigments are digested and removed via the lymphatics (4). This phenomenon has been correlated to the clinical observation that older tattoos respond better than younger tattoos to laser therapy, presumably due to decreased particle content (7). Indeed after each therapeutic intervention, there is an additional cycle of inflammation and reorganization of the tattoo constituents, which will affect the subsequent appearance. This process may take several weeks, necessitating periods of expectant management and observation between therapies.

TABLE 1 Injury Mechanisms and Common Particles of Traumatic Tattoo

Injury	Particle
Abrasion	Organic/carbon based Mineral
Explosion	Gunpowder
Civilian	Casing material
Military	Shrapnel
Industrial	Organic/carbon based Petroleum compounds Chemicals
Puncture	Carbon Inks

TREATMENT OPTIONS

The treatment options for traumatic tattoo can be classified as surgical, mechanical, chemical, and photothermic (Table 2).

SURGICAL

In certain clinical situations, full-thickness excision of traumatically tattooed skin may be the only intervention required. Excision of small, isolated, or linear areas of traumatic tattoo in the head and neck can be accomplished with excellent cosmetic results (8). Factors influencing the application of this technique include tattoo size, location, and pigment material. Patient factors such as hypertrophic scar or keloid formation must also be taken into account. Serial excision and tissue expansion may also be useful techniques in selected patients (9). Larger or solitary particles can be removed with either stab excision or punch biopsy. This can be effective for tattoos consisting of few particles and also as an adjunct to other forms of tattoo removal. For example, the efficacy of laser treatment decreases with increasing particle size and the excision of larger particles can decrease the total number of treatments required. Surgical excision may be desirable to the patient who wishes expedited treatment, as the period of tattoo reorganization is eliminated.

Standard closure options for excision sites are known to most surgeons. Situations in which full thickness skin grafting may be appropriate are few (8) but upper eyelid deficits typically respond well (4). Likewise split thickness coverage of full thickness defects in the craniofacial region is generally aesthetically unacceptable. Local flap closure techniques are ideally suited to full thickness excision wounds in the head and neck and are well known to reconstructive surgeons.

Split thickness excision has been employed in the management of traumatic tattoo but not routinely in the craniofacial region. Tissue can be removed tangentially with a dermatome or

TABLE 2 Traumatic Tattoo Treatment Options

Therapy	Pros	Cons
Surgical excision		
Full-thickness	Removes debris at any depth Definitive treatment	Scar formation Tattoo site/size limitations
Split-thickness	Good for superficial debris	Particle size/number limitation
Stab	Removes debris at any depth	Scar formation Particle size limitation Scar formation
Mechanical debridement		
Brushing	Effective acutely Satisfactory for moderate depth	Decreasing efficacy after first 24 hours Not effective for concavities/thin skin
Dermabrasion	Definitive for superficial debris	Particle depth limitation
Salabrasion	Good for superficial debris Ease of use	Scarring/dyspigmentation Painful
Chemical	Good for superficial debris	Scarring/dyspigmentation
Peeling agents (phenol, TCA)	Ease of use	Not widely used
Photothermic (laser)		
Argon	Good for colored debris	Painful Unpredictable scarring, especially in children
CO ₂	Widely available	Greater thermal damage
erb:YAG	More precise	Painful Scarring/dyspigmentation Not widely used
QS ruby, QS alexandrite	Good for larger particles Less thermal injury	Only efficacious for darker pigments May require multiple treatments
QS Nd:YAG (+ KTP crystal)	Good for moderate depth Wide pigment spectrum Moderate dermal penetration	Mild discomfort May require multiple treatments

under direct magnified excision (10,11). Partial thickness surgical debridement can be time consuming and results are operator dependant. Care must be taken to remove all the deep pigment before healing takes place (8). Resurfacing can be either through epithelialization, split thickness skin graft, or through cultured epithelial autograft. Tissue grafting usually results in a suboptimal appearance secondary to differences in color and texture match, especially on the face. The degree of post treatment pigment change and hypertrophic scarring is directly related to the amount of dermis excised, which penalizes the aggressive pursuit of deeply embedded pigments.

MECHANICAL

Acute debridement of traumatic tattoo by irrigation and brushing has long been a treatment mainstay (1,11,12). Optimal cosmetic results are obtained if the brushing is performed early (1,4), ideally within the first 24 hours, before reepithelialization has occurred (13). The exudative nature of the fresh wound provides the best environment for the exogenous removal of deposited particles. Delayed brushing techniques have been described (14), but the presence of dermal fibrosis and reconstitution of the superficial layers during healing mandates further injury to access the pigments. This has been associated with greater overall scar formation. Brush debridement can be painful; therefore local and systemic analgesia should be liberally employed. Large areas requiring irrigation and brushing should be treated under general anesthesia. Pulsed lavage can be very useful at the onset of debridement and may be all that is required. Healing is accomplished by reepithelialization and generally takes 2–3 weeks (13). The site should be treated with antibiotic ointment until healing is complete. Powder burns and explosive tattoos typically respond less favorably to brush debridement compared to punctures or abrasions (4).

Dermabrasion has been well described for the treatment of traumatic tattoo (8). Superficial particles are removed by friction and deeper pigments are mobilized to the surface by the resultant exudative inflammatory reaction (15). The cosmetic results are generally better with superficial traumatic tattoos, which require less overall tissue damage (4). Multiple treatments are often required for traumatic tattoos and dyspigmentation and scarring often result to varying degree. Dermabrasion can be difficult to apply to certain areas of the face such as the nasolabial folds and eyelids (13).

Salabrasion is an older technique whereby superficial dermabrasion is accomplished by the application of table salt into the tattoo site. The irritative effect of the salt enhances the exudative response of the newly created wound, thereby exploiting tissue edema to mobilize retained particles. A crust forms at two weeks and separates by five weeks leaving healed skin behind. Several treatments may be required. Complications such as hypopigmentation, pain, and scarring are frequent and subsequently limit the use of salabrasion in modern medical practice (15,16).

CHEMICAL

Assorted chemical treatments have been used in the management of tattoos but most are not optimal for traumatic tattoos of the craniofacial region. Historically, tannic acid was used to induce damage to the epithelial layer with subsequent eschar formation and sloughing of tissue. This carries away embedded particles but the varying depth of traumatic tattoo pigments yields incomplete and aesthetically poor results in the majority of cases (17). Phenol, TCA, and other modern peeling agents similarly only safely affect the superficial epidermal layers and leave the deeper pigments. Dosing sufficient to affect the deeper layers would enhance any potential pain, scarring, and dyspigmentation (8). Accordingly these techniques are not routinely employed, except for the treatment of the most superficial traumatic tattoos. Other chemicals of historical note are salicylic acid, sulfuric acid, and zinc chloride, none of which are in routine use today (5).

Imiquimod is a topical immune response modifier that has shown promise in the treatment of assorted cutaneous disease and has recently been experimentally applied to professional tattoos. Guinea pigs with newly created tattoos were treated with high-dose imiquimod 5% cream and found to be pigment free at 28 days. Enhanced immune activity within the skin facilitated rapid clearing of the relatively inert tattoo pigments. This novel substance may hold promise for the medical treatment of traumatic tattoo, especially in the acute phase (18).

PHOTOTHERMIC

Multiple modalities have been employed to introduce thermal energy to tattooed skin. Earlier methods consisted of direct application of heat or cold to the target skin to induce injury. The subsequent necrosis of the pigmented tissue would remove the particles included in the eschar. Treatments with liquid nitrogen, electrocautery, or electrodesiccation all leave marked scarring and dyspigmentation and have been abandoned in modern tattoo management (8).

The delivery of laser energy to, and through, tattooed skin has revolutionized the treatment of all forms of tattoo. Pigmented areas and particles can be targeted with extreme precision and minimal discomfort. Differing wavelengths, fluences, and pulse durations can be exploited to isolate specific chromophores and tissue depths. Although no laser is free of complications, generally dyspigmentation is transient and scarring is minimal, especially compared to abrasive techniques (19).

Initial attempts at laser ablation of tattoo pigment were less than ideal. The argon laser functions at wavelengths of 488 nm and 514 nm. The energy is absorbed by darker pigments, which produces heat and resultant local tissue vaporization. Collateral damage is an issue and unfortunately because of the similar energy absorption profile of melanin, the argon laser produces too much dyspigmentation and scarring relative to more modern lasers. The scarring can be unpredictable, especially in children. The CO₂ laser has a wavelength of 10,600 nm and selectively targets water molecules. The net result is also that of superficial tissue vaporization and healing is by reepithelialization. Deeper layers of tissue can be accessed with serial passes but the resultant discomfort can be significant. Both the argon and CO₂ lasers ultimately function as very precise dermabraisers and have the same associated complications of retained deep pigment, hypertrophic scar, and dyspigmentation (8). When the pigmented particle is encountered, vaporization or extrusion occurs (12).

The erb:YAG laser functions at a wavelength 2940 nm and like the CO₂ laser, selectively targets water molecules. Tissue vaporization results but due to higher fluences (10–20 J/cm²) larger pigment particles (>40 micrometers) can be affected with less collateral damage. The erb:YAG laser generates less heat and as a result produces less local thermal injury relative to the argon or CO₂ lasers. The precise tissue destruction and large particle efficacy make the erb:YAG laser useful for traumatic tattoo treatment in thinner, delicate skin that heals well, such as the eyelid (19).

Q-switching technology allowed for increased energy delivery with pulse durations in the nanosecond range. This decreased transmission time greatly reduces the thermal effects on the nontarget tissues while delivering energy to the target species (7). The particles absorb laser energy in pulse durations shorter than their thermal relaxation times. The resultant temperatures are in excess of 1300°C, which causes rapid expansion in the target chromophores. A photo acoustic shock wave is produced which shatters the pigmented particles. This phenomenon is known as selective thermolysis (20). An audible snap can often be heard with the fragmentation of the target pigments (6,12).

The first such laser to gain widespread acceptance in the treatment of traumatic tattoos was the Q-switched ruby laser. With a wavelength of 694 nm, the Q-switched ruby laser targets dark blue and black chromophores. The Q-switched alexandrite laser emits energy with a wavelength of 755 nm and also targets the darker pigments found in traumatic tattoos. Fluences of 4–10 J/cm² for both devices effectively treat most chromophores found in traumatic tattoos with minimal scarring. The absorption spectrum of both lasers is shared by melanin, which dilutes the effect on the target pigments and enhances the dyspigmentation witnessed during treatment. This also restricts usefulness in patients with Fitzpatrick skin classes IV–VI (21,22). Energy that is absorbed by melanin is energy that does not reach the target particles and subsequently the number of doses required to treat increases. Discomfort during treatment is minimal and dyspigmentation is usually transient, resolving in 6–12 months. As a result, both lasers have gained widespread acceptance for the treatment of traumatic and intentional tattoo.

The Q-switched Nd:YAG laser has a wavelength of 1064 nm. Decreased energy absorption by melanin produces less dyspigmentation, both transiently and long term. The very short pulse width and greater energy delivery produce a more violent photoacoustic shock wave which can result in slightly more collateral damage relative to the erb:YAG laser. Most Nd:YAG lasers are coupled with a KTP crystal which halves the wavelength (532 nm) and increases the

affected pigment spectrum. All Q-switched lasers produce some degree of discomfort and scarring, but it is generally much less than other methods of tattoo removal.

MANAGEMENT

Patients present for medical attention with traumatic tattoos in either the acute phase or the chronic phase. Careful attention should be paid to the history of the traumatic event and any issues surrounding healing tendencies, such as keloid formation. If possible, serial photographs greatly aid in discussing treatment plans and help identify progress. Patients are routinely counseled to avoid sun exposure for six months after the treatment to minimize scar discoloration (21).

ACUTE

The majority of patients who present acutely with traumatic tattoos have been involved in some accident that requires a trauma evaluation. Any historical information should be gathered, especially with regard to the nature of the tattooing substance. Plans should be made for brushing and irrigation within the first 24 hours. Brush debridement should remove a significant portion of the embedded debris and provide a sample for identification if a likely determination could not be obtained from the history. Larger particles can be removed at this time via stab incisions or small punch biopsy instruments. Appropriate wound care should follow with topical antibiotic ointment for 7 to 14 days while reepithelialization takes place. Follow-up should be arranged to evaluate the degree of residual tattooing and to make plans for further treatment if required.

CHRONIC

These patients typically have had their traumatic tattoos for a longer period of time and the opportunity to brush debride the wound has passed. After evaluation of the historical and clinical aspects of the tattoo, discussion should focus on the assorted treatment modalities and their durations. The patient should be informed that laser therapy may take multiple treatments and several months to complete whereas surgical excision may be definitive in a single session. Puncture tattoos involving carbon-based pencil tips respond well to laser therapy but are also amenable to removal with small hair follicle punches. Prior to the initiation of laser therapy, reference must be made to the nature of the tattooing pigment. Caution should be taken before considering laser treatments on combustible elements and metallic entities and a test spot should be tried. When laser energy is applied to intradermal gunpowder, ignition can occur producing local tissue damage, cavitory spread of pigment, and pitted scars (23).

Four-week intervals between treatments are sufficient to allow healing of the affected tissues, but longer intervals allow for greater native clearance of the fragmented tattoo particles. The value of serial observation must not be underestimated and may ultimately result in fewer therapeutic interventions and fewer complications.

CONCLUSION

Despite the great variety of traumatic tattoo presentations and morphologies, aesthetically acceptable treatment should be the expectation. Early debridement followed with delayed excision or laser therapy can minimize dyspigmentation and scarring to produce cosmetically excellent results with minimal patient morbidity. The visibility of craniofacial tattoos, discolorations, and scars highlights the importance of well-planned, patient, and methodical management.

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14 Composite Reconstruction of Midface Defects

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INTRODUCTION

The cheek, while often thought of as a fairly innocuous part of the facial anatomy, nevertheless occupies a very visible part of the face. Reconstruction of the cheek is often necessary and while it does not compare in intricacy and visual impact with eyelid, lip, or nasal reconstruction, skillful restoration is nevertheless imperative. Because of its position in the face, however, it occupies a less crucial position than the central facial structures. This allows for some leeway in our reconstructions. All aspects of both cheeks cannot be seen together. This is in contrast, for example, to the nose where right and left alae are instantly comparable. So a reasonably accurate replica of the intact contralateral cheek will result in a very satisfactory reconstruction, while a less than accurate alar reconstruction will provide an inferior result.

As with all reconstructions, it is important to consider what tissue is being replaced. In the case of the cheek, that is easy on first impression. The cheek consists of a soft-tissue envelope of skin, subcutaneous tissue, muscle, and buccal mucosa draped over a bony framework, the most prominent part of which is the zygomatic prominence. Within this soft tissue is embedded the parotid gland and duct and the facial nerve. Furthermore, consider the texture of the cheek. In females, it is smooth and soft. In males, it is partially hair-bearing and less smooth. The other important feature in consideration of cheek reconstruction is skin color. Under normal circumstances, we often choose our reconstructive options based on tissue availability and size. In the head and neck in general and in the face in particular we must also consider the fact that our reconstruction is going to be the visual evidence of the surgery our patient has undergone. A cheek, for example, can be elegantly reconstructed in terms of contour, movement, etc., but if the skin color is strikingly different from the rest of the face, the reconstruction will stand out. Finally, while we can think of the cheek as a separate esthetic unit, reconstruction of the cheek will frequently impact on nearby units, for example, the pull on the lower eyelid from a cheek advancement flap. Reconstruction of the underlying bony skeleton is obviously an important part of cheek reconstruction. The integrity of the contour of the underlying bony skeleton is important in maintaining facial symmetry. Bony reconstruction of the cheek is seldom an isolated necessity, particularly in the context of tumor ablation and reconstruction. In this situation, we are generally dealing not only with the bony cheek but also with the whole maxilla. This brings us into the area of orbital palatal and nasal reconstruction. A detailed description of maxillary reconstruction is beyond the scope of this chapter, but it is important to realize that the two, cheek and maxilla, cannot always be separated. This chapter focuses on soft-tissue reconstruction of the cheek, but the principles of bony reconstruction will be outlined.

GENERAL PRINCIPLES

As with all areas of reconstruction, local tissue works best in terms of replacing like with like. It works best for exactly the reasons alluded to above. It provides tissue of like texture, similar color, and with identical characteristics in terms of dermal appendages, hair growth, and so on. This is the tissue of choice where at all possible. If sufficient tissue is not available locally and the nature of the disease process allows it, tissue expansion becomes an alternative method of providing sufficient local tissue to cover the defect. While tissue expansion is a seldom utilized modality in the context of cheek reconstruction, it does have a place and should not be discounted, although it is not always an option. In some cancer reconstructions, for example, we cannot afford the luxury of expanding adjacent tissue to effect the reconstruction. The nature of

the disease in this case demands that we ablate and reconstruct simultaneously. It is only in situations where local tissue is not available that distant tissue is considered and in that situation, donor tissue choice is important.

LOCAL FLAPS FOR CHEEK RECONSTRUCTION

The amount of local tissue available for reconstruction will depend on several factors. The size of the defect is obviously important in determining the amount of tissue left. However, the age of the patient is also important. Older patients in general have more laxity and defects that can be reconstructed in older patients with relative ease will demand more complex repair in a young patient. Cheek wounds can frequently be converted to an ellipse and closed directly. It is important to be cognizant of the relaxed skin tension lines and to keep all scars parallel to these lines if possible. In the elderly patient, these are usually easily visualized and incisions appropriately planned. All manner of local flaps can be used for defect closure and first principles apply: (i) keep incisions parallel to relaxed skin tension lines, and (ii) avoid traction on vital structures that may cause secondary deformity. As far as the cheek is concerned, the most common anatomic unit thus affected is the lower eyelid. It is very easy to produce an extrinsic ectropion from injudicious use of local flaps. It is just as easy to avoid such complications through careful planning.

Cheek Rotation Advancement Flap

This is the most common approach to cheek reconstruction and remains the basis for the most successful cheek reconstructions. It is important to remember some basic principles here. While there is some laxity running across the cheek, particularly in the older patient, it is limited. For that reason, the rotational element of the flap is also important. These flaps can be based anteriorly as described by Juri and Juri (1,2). They can also be based posteriorly as described by Stark and Kaplan (3) (Fig. 1A and B). Basing the flap posteriorly (Fig. 1B) allows mobilization of the jowls so that this excess can be moved up onto the face. Basing the flap anteriorly (Fig. 1A) allows for mobilization of neck skin up onto the face. The arc of rotation of the flap can be increased by extending the incision down onto the chest (4,5) (Fig. 1A). This incorporates a back-cut that not only allows for better mobility of the flap but also facilitates closure of the secondary defect.

One of the most important pitfalls to avoid in using this flap is that of producing an ectropion. In order to avoid this, the flap should be suspended from the underlying bony skeleton. This can be achieved either with the aid of periosteal sutures (6) (Fig. 2A) or with an anchoring device such as a Mitek anchor (7). This provides the patient with a tension-free

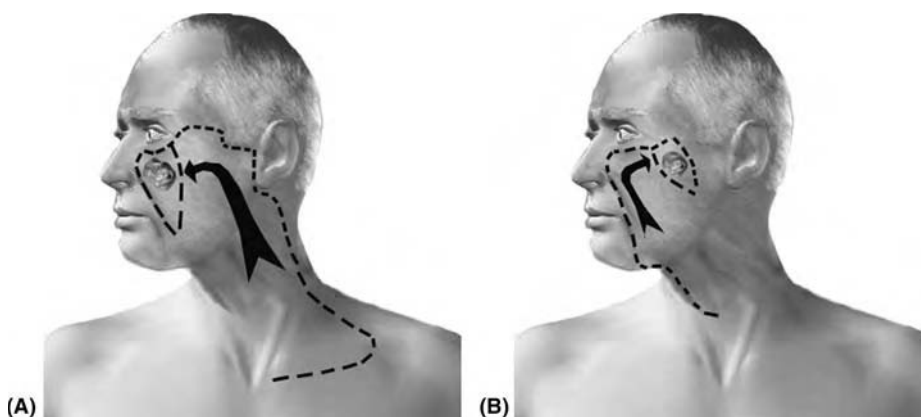


FIGURE 1 The cheek rotation flap can be based laterally (A) or medially (B). The laterally based flap can be extended down to the clavicular region if extensive skin coverage is needed. The medially based flap is useful in patients who have extensive jowls. Arrows show the vector of advancement and rotation.

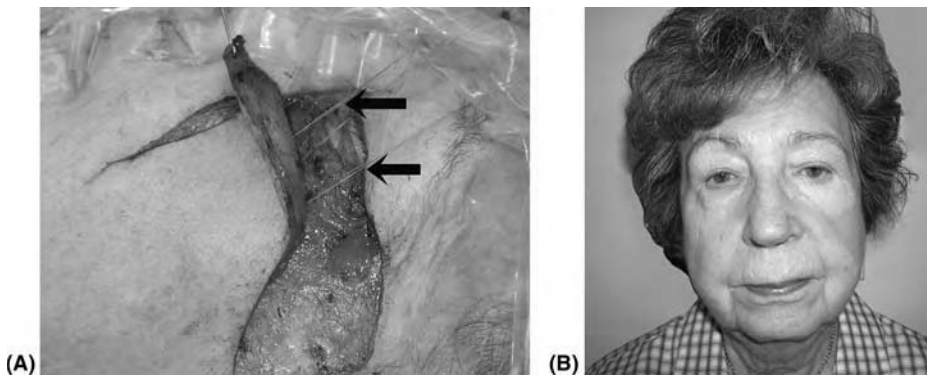


FIGURE 2 (A) The flap is suspended from the periosteum of the infraorbital rim (*arrows*) in order to ensure tension-free closure and to prevent ectropion. (B) The final result shows good symmetry and absence of significant ectropion.

closure and prevents downward traction on the eyelid (Fig. 2B). Closure of the defect is important. Care must be taken to avoid advancing hair-bearing skin from the sideburn area onto the cheek in female patients. For that reason, it is best to place the incision around the sideburn in these cases (Fig. 1A). This can also facilitate closure so that the sideburn is not altered. As the flap is rotated the resulting dog-ear is excised. It is usually possible to place this scar either in the nasolabial fold or parallel to it.

Submental Artery Flap

The submental flap is a very useful addition to our armamentarium for reconstructing defects of the cheek. It has the advantage of providing excellent quality skin of a similar color. It can easily reach the cheek and the donor defect is nicely hidden under the chin. In males, the issue of beard growth may be an important consideration especially if the flap is being used anywhere near the lower eyelid. Hair growth in this area is obviously not normal and may preclude use of this flap in this particular situation. However for most small to moderate sized defects the submental flap is an excellent choice (Fig. 3). The flap is based on the submental branch of the facial artery and it can be tunneled up into the cheek (8). The arc of rotation can be increased in two ways: antegrade and retrograde (9). As the submental artery comes off the facial artery trunk, the latter continues up over the mandibular border to reach the face. If the facial artery is divided after the submental branch is divided, the facial artery can be dissected back toward its origin from the external carotid. Usually, in doing this, an extra centimeter or two of pedicle lengths can be realized. Alternatively, the facial artery can be divided before it gives off the submental branch. In this situation, the flap is perfused through retrograde flow from the facial artery. This reversed that flow pattern of perfusion is adequate to sustain the flap (9).

FREE TISSUE TRANSFER

For larger defects, cheek rotation flaps may not be sufficient to achieve closure. In this circumstance, a free flap is required. Frequently, the defect is such that more than soft-tissue reconstruction is required. While reconstruction of maxillectomy defects is not the subject of this chapter, it is important to be aware of the important issues that influence the choice of reconstruction in this clinical setting.

Maxillectomy Defect Reconstruction

Cordeiro has proposed a classification system and treatment algorithm for reconstruction of these defects (10). There is controversy among reconstructive surgeons about whether one should reconstruct these defects with flaps containing multiple skin paddles (11) or simply to fill the defect with soft tissue and allow the mucosal surfaces to remucosalize (12). There is much debate between reconstructive surgeons and prosthetists about the issue of whether or

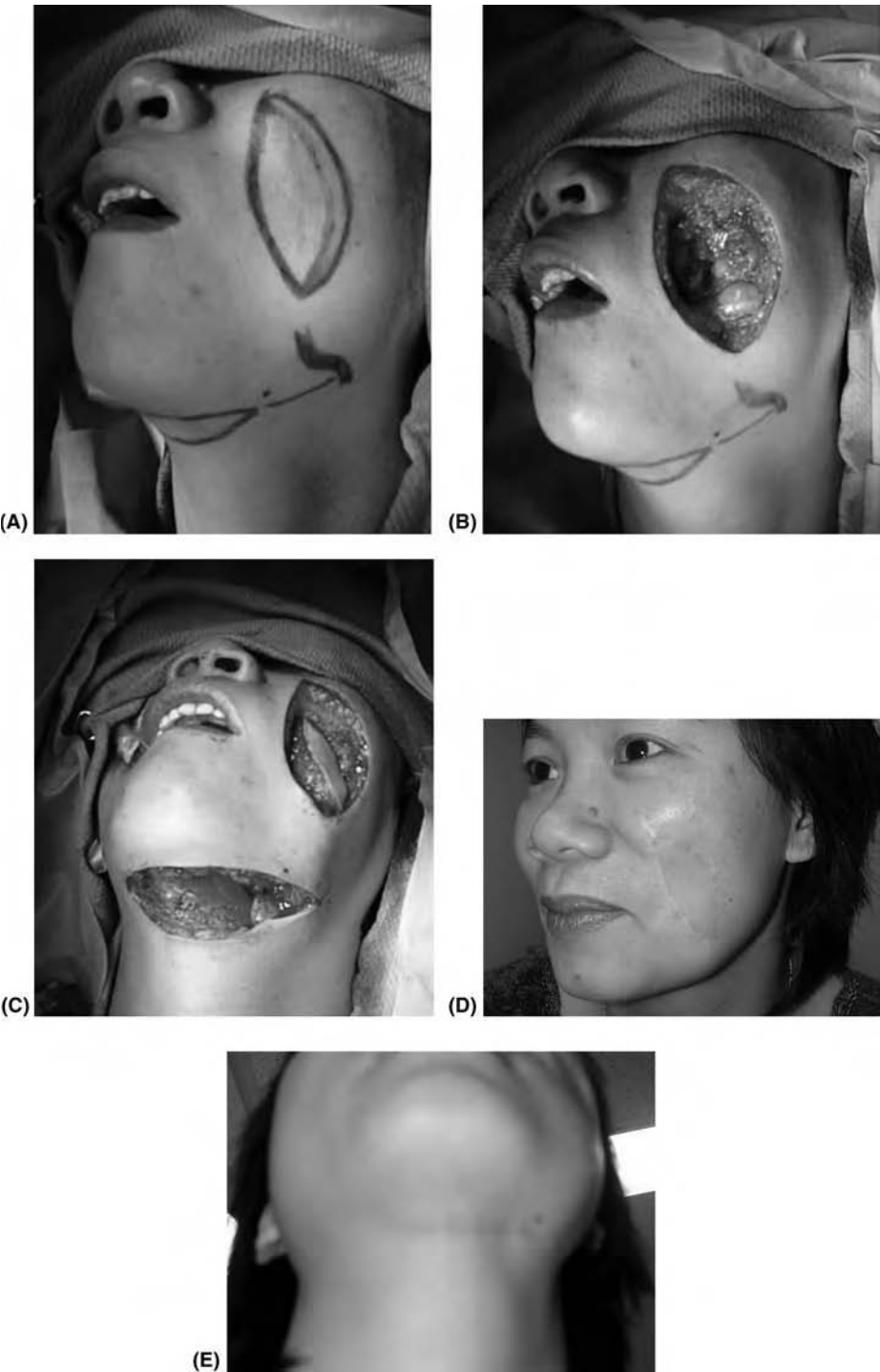


FIGURE 3 (A) Young woman with soft-tissue sarcoma of left cheek. Scar indicates incisional biopsy site. (B) Appearance of cheek postablation. (C) The submental flap has been elevated and tunneled into the cheek defect. (D) Final postoperative appearance two years later. (E) Donor scar two years postoperatively.

not it is better to obturate the maxillectomy defect with a flap, the former claiming that flap reconstruction is better, the latter bemoaning the fact that fitting a dental prosthesis is very difficult if the cavity has been obturated. Yamamoto espoused the buttress principle in reconstructing these defects (13), while Brown (14) has proposed an elegant method of reconstructing this defect with inner table iliac crest and internal oblique muscle based on the deep circumflex iliac artery. This reconstruction allows not only for bony reconstruction and cavity obturation but also allows for dental rehabilitation with osseointegrated implants. A detailed description of reconstruction of the maxillectomy defect is beyond the scope of this chapter.

Soft-Tissue Cheek Reconstruction

When reconstructing the cheek with a free flap, the choice of flap becomes very important for reasons alluded to at the beginning of this chapter. The choice is determined by a number of issues. Bulk, or lack of it, may be important depending on whether or not one is reconstructing a surface defect or a through and through defect. The option of subsequent thinning of an over-bulky flap is always a reasonable one. For through and through defects, an epithelial surface will be required for lining as well as cover. One of the most important issues in choosing a donor site is that of color. A good color match is, in many ways, the most important feature of the reconstruction. If the color match is good, many imperfections will not be noticed whereas if the match is bad, the reconstruction will not look as good no matter how well it has been executed. Color match is also related to ethnicity. There is less difference in regional skin color in darker skinned patients. Studies have been carried out on patients with Fitzpatrick type II–III skin (15) showing which donor sites are best (16). In most cases, flaps harvested from the upper trunk work best and in my own practice, the circumflex scapular territory, either scapular or parascapular, works well.

Scapular and Parascapular Flaps

The skin territory of the scapular and parascapular flaps is sufficiently large to allow for closure of the largest cheek defect while at the same time closing the donor defect directly. Depending on the size of defect, the flap can be folded on itself in the case of through and through defects, to provide lining and cover (Fig. 4) or alternatively, scapular and parascapular flaps can be harvested on the transverse and descending branches of the circumflex scapular artery respectively (Fig. 5), to provide lining and cover. The latter arrangement allows more leeway in terms of inset as both skin paddles can move independently of each other. The thoracodorsal perforator flap incorporates the same territory as the circumflex scapular system. Figure 6 shows the relationship of the first dorsal perforator of the thoracodorsal system to the circumflex scapular artery. In some situations, it is nice to have an option in terms of pedicle placement and length. One of the biggest drawbacks of using scapular skin is the fact that flap harvest and ablation cannot be done simultaneously. Patient repositioning can be avoided by harvesting the parascapular skin territory and placing the patient on a beanbag in the semi-supine position with the arm free-draped. The scapula can also be taken with bone and this can be used effectively to reconstruct the bony contour of the cheek (Fig. 7).

Anterolateral Thigh Flap

The anterolateral thigh flap is an alternative to the scapular/parascapular flap. Color match is not as good in lighter skinned patients. However in darker skinned individuals the color difference is less marked. This flap has the advantage of facilitating simultaneous harvest and tumor ablation. This may be desirable in patients in whom comorbidities predicate a shorter operation. The anterolateral thigh flap provides adequate skin quantity and quality. It can be harvested with or without fascia. Suprafascial dissection provides a thinner flap (17) which, in the context of cheek reconstruction, is optimal. In female patients, bulk may still be an issue as the thigh in older female patients may have a significant amount of subcutaneous fat. This fat can be safely trimmed without compromising flap vascularity (18). In male patients, hair growth may be an issue that may limit use of this flap for cheek reconstruction. However in most cases this is not a problem. The donor defect is very acceptable and in almost all cases can be closed directly. This flap can provide a very satisfactory solution for reconstruction of large cheek defects.



FIGURE 4 (A) A 52-year-old patient with extensive recurrence of a basal cell carcinoma of the right cheek, following previous surgery and radiation. (B) Preoperative markings for external cheek resection (*outer line*) and buccal mucosa excision (*inner line*). (C) Scapular flap being inset. *Black arrow* shows de-epithelialized segment of flap, which has been folded on itself to also provide internal lining (*white arrow*). (D) Final postoperative appearance three years later. Patient also had a static sling to the oral commissure.

Other Flaps

The radial forearm flap has also been used in cheek reconstruction. The thin nature of this flap makes it amenable to folding for through and through defects, but the author's experience has been that even a folded radial forearm flap is too thin. The rectus abdominis myocutaneous flap has also been extensively used in this situation. While it provides adequate tissue, both color match and bulk may be unacceptable. Use of the deep inferior epigastric artery perforator (DIEP) flap provides a somewhat thinner flap but, in his practice, it is not a front line flap for this application.

Donor Vessels in Cheek Reconstruction

In most of these cases, a neck dissection is part of the treatment plan so that donor vessels are easily available. The facial and superior thyroid vessels are most commonly used. The superficial temporal vessels are also generally available and while some authors have reservations about their use, our experience has been good (19).

Facial Nerve

A discussion on cheek reconstruction is not complete without considering the facial nerve. A full discussion on management of the facial nerve is beyond the scope of this chapter, but it

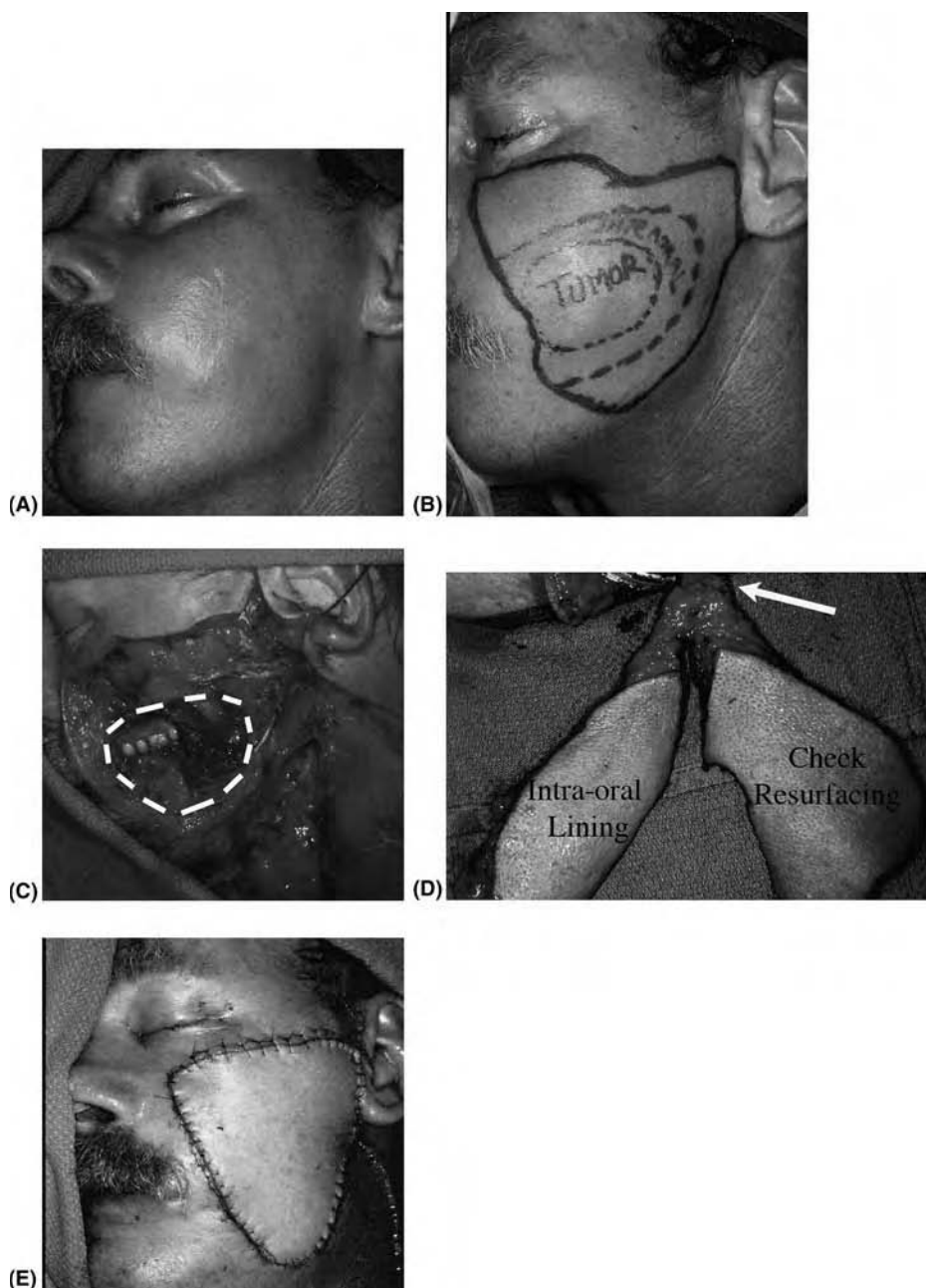


FIGURE 5 (A) A 47-year-old man with soft-tissue sarcoma of cheek. Scar depicts site of incisional biopsy. (B) Preoperative markings show external resection and lining resection in relationship to the tumor. (C) Shows the resection. White, broken line depicts extent of buccal mucosal resection. (D) Scapular and parascapular flaps, one paddle for intraoral lining, the other for external skin cover. The *arrow* points to the pedicle. (E) Appearance of flap at time of inset.

is important to consider the facial nerve in the context of cheek reconstruction. A decision frequently needs to be made with regard to facial nerve function in situations where the nerve is sacrificed. Options include primary nerve grafting, functional muscle transfer as well as static sling operations. The decision on which modality to use depends on several factors. For example, in an elderly patient with a poor prognosis the chance of getting good

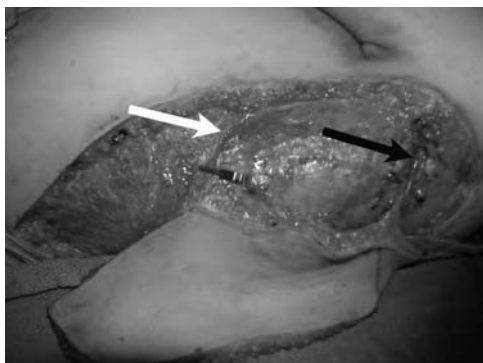


FIGURE 6 The relationship of the thoracodorsal perforator artery (*white arrow* and vascular clamp) to the circumflex scapular artery (*black arrow*).

function from primary nerve grafting is remote and a free functioning muscle transfer is not an option in this situation. However, the patient's quality of life will be significantly improved by use of static slings. We routinely use slings to the oral commissure as well as to the lower eyelid. As well, consideration should be given to the use of gold weights in the upper eyelid as well as brow lift. In the elderly cancer patient, a direct excisional brow lift is very simple and the scar is well tolerated. In this situation, the benefit of the lift outweighs the disadvantage of the scar. We have more recently used plantaris tendon for static slings and found it to

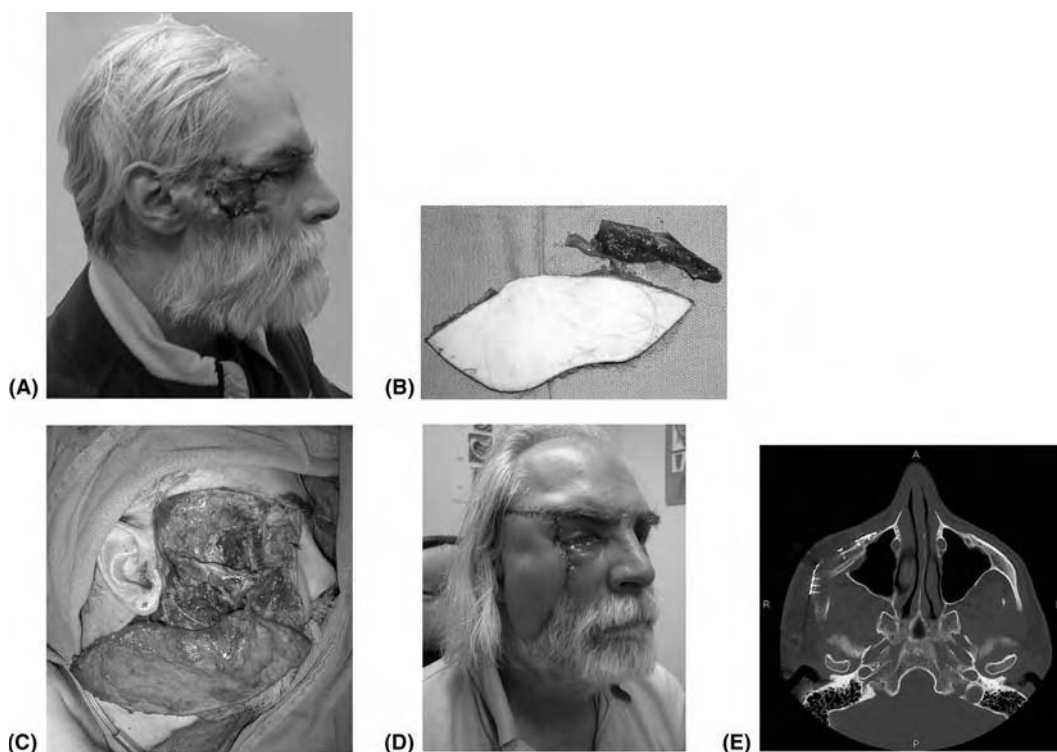


FIGURE 7 (A) A 49-year-old man with extensive neglected basal cell carcinoma of left cheek with involvement of underlying zygoma and lateral orbit. (B) Scapular osseocutaneous free flap harvested. (C) Bony reconstruction (see miniplate) with vascularized scapula. The skin paddle is at the bottom of the picture and the pedicle can be seen extending from the bone into the skin paddle. (D) Immediate postoperative appearance. (E) Postoperative CT scan showing position of bony reconstruction.

work better than fascia lata, which tends to attenuate over time. In younger patients, use of a nerve graft should be considered. In these individuals, we will also use static slings to give the patient immediate benefit in terms of resting facial symmetry as nerve recovery is somewhat protracted in time as well as uncertain in extent. This may be particularly relevant when the variable of post-operative radiation is added to the confounding influences.

Finally, contour is an important aspect of cheek reconstruction. Some ablative procedures, such as parotidectomy are associated with a postoperative contour defect that can be very disturbing for the patient. More radical ablations can include the whole of the parotid gland as well as the facial nerve. In these situations, a flap can be used to fill in the contour defect with excellent effect.

SUMMARY

Effective reconstruction of the cheek is important in maintaining facial esthetics. Color match is vitally important and a well-matched reconstruction can hide other imperfections that one can not get away with in other anatomic regions. Contour is also important. Excess bulk is to be avoided but is more acceptable than lack of bulk, as secondary debulking is always an option. Care must be taken to avoid unwanted secondary effects on adjacent structures such as the lower eyelids, and consideration should always be given to facial nerve function.

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15 | Blepharoplasty

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INTRODUCTION

Even minor variations in the normal appearance of the eyelids are readily recognized. Eyes, with associated lids and brow, are one of the prime foci of attention when one looks at the face. The eyes may enhance beauty, reflect emotion, and even define character. Because of their functional and aesthetic importance, surgery of this region is best done following considerable analysis, and with technical precision. The treatment of facial aging in this region is discussed in this chapter.

Normally with advancing age, there is a weakening of ligamentous support structures, and elongation of the skin of the eyelids. The medial and lateral canthi and the restraining layers of fat in the upper and lower lids are particularly vulnerable to these aging effects. In addition, at the level of the infraorbital rim, soft tissue prominence related to fat overlying the orbital rim descends inferiorly resulting in a depression in the orbital rim giving rise to an abnormal hollowing out of the lower lid, and folding of the soft tissue in the upper midface. The term, blepharoplasty, comes from the Greek, blepharus (eyelid) and plasty (to reshape). It refers to techniques, which have evolved over time to attempt to correct malpositions of the eyelid contour due to fat herniation and skin and tension laxity (e.g., canthopexy). More recent techniques have emphasized the need for reshaping rather than resecting soft tissues because more aggressive surgical removal of orbital fat in middle age may exaggerate the “hollowed out”, or prematurely aged, appearance of the eyes later (1–6). Great strides have been made, conceptually, as well as technically, in the management of lower lid and associated midface deformities over the last 20 years. Loeb (7,8) recognized that the most logical approach to addressing fatty prominence in the lower lids was related to treating the prominence of the lid fat not as a tumor, which needs to be removed, but as a hernia, which needed to be repaired. This idea has been enhanced by numerous others subsequently, in particular de la Plaza (9) where lower-lid ligamentous structures were advanced to help support the prominent fat protrusions and create a more normal form in the lower eyelid. Further emphasis has been given to the need for adjunctive canthoplasty, particularly when blepharoplasty is accompanied by facelift procedures, as described by Hamra (1).

In the upper eyelid, regeneration includes not only analysis and correction of lid fat herniation, skin excess, and ligamentous structure, but also the shape and position of the brow.

Concepts of facial rejuvenation in the periorbital region should be considered, therefore, as a multistep process which includes understanding of the normal and aesthetic brow position, the most aesthetic upper eyelid contour, crease and position, and the configuration and lower lid contour as it blends into the upper cheek soft tissue of the profile (10–12).

ETIOLOGY

The majority of patients seeking blepharoplasty develop deformities related to aging of tissues, which may be exacerbated by excess sun exposure, smoking, and to a lesser degree, familial inheritance, exposure to allergens, and sleep deprivation.

PERTINENT ANATOMY—NORMAL AND PATHOLOGIC

The eyebrow typically has an aesthetic appearance, by having a gentle arching of the brow from medial to lateral with the high point located, approximately, at the junction between the medial

two-thirds and the lateral one-third of the brow in females. There is a slightly more planer, or “flatter” contour in males. The brow position is normally kept in location, at or above the superior orbital rim by forehead musculature (frontalis) and particularly restraining ligaments at the level of the lateral periosteal border of the superior orbital rim with the brow. Brow shape can also influence perception of the patient’s mood as well as well being (10). For instance, a downward lateral slanting eyebrow may be perceived by the viewer to be sadness. A downward slanting of the medial brow may generate a perception of anger.

The supraorbital nerve is located on a sagittal plane at the medial border of the pupil. The medial corrugator and procerus muscles are located at the medial basal forehead and nose, and are associated with wrinkling not only in the dorsum of the nose, but also in the medial orbit, they produce the “frown lines” of the brow region (13). The skin is relatively thick at the level of the eyebrow, itself, but as one proceeds from the brow to the lash border, it becomes progressively thinner, and ultimately represents the thinnest skin of the body, due primarily to a shallow dermis. Beneath the eyelid skin is a trace amount of fatty tissue, and below this is the orbicularis muscle. The orbicularis muscle is divided into three layers: the first two are collectively known as the palpebral portion of which the pretarsal is first, and is slightly wider in the upper lid than the lower (approximately 1 cm vs. 5 to 7 mm in the lower eyelid). This corresponds to the difference in height of the tarsal plate in the upper and lower lids. This layer is important, as it is a prime support for opposition of the eyelid to the globe, so as to prevent corneal exposure and drying. The second portion of the palpebral orbicularis muscle is the preseptal muscle, which extends from the tarsal border to the margin of the orbital rim, in both the superior and inferior lids. Surrounding this is the third, or orbital portion, of the orbicularis muscle. The innervation of the orbicularis muscle is derived primarily from the zygomatic branch of the facial nerve entering laterally primarily, but there also is a significant portion of the pretarsal nerve innervation extends from the buccal branch of the facial nerve medially, particularly in the lower lid (14). Beneath the orbicularis muscle is the orbital septum, which is of varying thickness depending on the age of the patient and the location within the height of the lid. It serves as the major restraining layer for the orbital fat beneath it. It is anchored at the orbital rim peripherally and the distal borders of the tarsus centrally. The major periorbital fat is located deep to the orbital septum, and both the extraocular muscle and the lymphatics, and the vascular supply to them are located within this space. The medial and lateral attachments of the eyelids are the medial and lateral canthi, respectively, representing condensations of fibrous tissue from the orbicularis muscle, particularly the palpebral portion in the eyelid. Within the confines of the medial canthal tendon (anterior and posterior leaves) is the lacrimal sac. The canaliculae from both the upper and lower lids traverse below the level of the orbicularis muscle to the sac from punctae located at the free margin of the lids medially. The anterior leaf of the medial canthal tendon is a stout fibrous structure, which is primarily responsible for normal positioning of the medial palpebral fissure. The posterior leaf of the medial canthal tendon is a less fibrous structure, with contractile muscular elements within it. The posterior leaf contractions help “pump” the lacrimal sac to evacuate it and create the suction of the tears from the conjunctival surface of the lids to progress into the nose through the nasolacrimal duct.

The lateral canthus has attachments to the lateral orbital wall at the level of the bony Whitnall’s tubercle at the frontal process of the zygoma. The expansion of this fibrous attachment is known as Whitnall’s ligament. It serves as a fulcrum-like division of the soft tissues in the upper eyelid around which the levator palpebral muscle pivots in actions of elevating and lowering of the upper eyelid.

The orbital septum of the upper lid attaches inferiorly to the anterior superior cephalad one-third of the tarsus. The sympathetically innervated, Müller’s muscle, attaches directly at the superior border of the tarsus. Small degrees of upper lid ptosis are attributable to sympathetic deinnervation of this muscle in the upper eyelid, and a similar, though to a lesser degree of elevation of the border of the lower lid. The tarsus, itself, is a fibrous structure containing no cartilaginous elements. Beneath the tarsus, is located the conjunctiva containing multiple forms of cells contributing to the wetting of the corneal surface, to include meibomian glands, the goblet cells, which secrete polysaccharide and mucus materials. The major gland contributing to wetting of the lids, however, is the lacrimal gland located in the upper outer quadrant of the

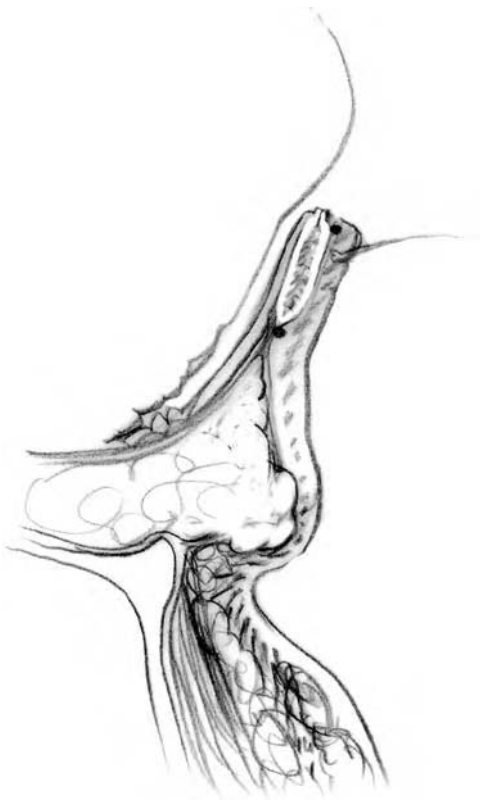


FIGURE 1 Schematic drawing of lower eyelid anatomy associated with aging. Reprinted with permission, *Plastic and Reconstructive Surgery*®.

orbit. It provides largely an aqueous fluid which combined with the secretions of meibomian glands and the mucin from the goblet cells, provides a multilayered tear film over the corneal surface. With aging, these lubricating structures tend to be less efficient.

In the lower lid, the structures are very similar to that of the upper lid. The main difference in this being that the tarsal plate is shorter in height, 5 to 7 mm at the mid papillary line as opposed to 10 to 11 mm in the upper lid, and the lower lid excursion is not as great contributing to only 2 to 3 mm of movement, with downward gaze, as opposed to a normal upper lid movement of approximately 12 to 15 mm. The lower lid analogous structure to the levator palpebral muscle is the capsulopalpebral fascia. It represents a condensation of the inferior oblique and inferior rectus muscle fascia in the lid and inserts just deep to but in combination with the septum. At the inferior border of the orbit is the suborbital orbicularis fat (SOOF), which is insinuated between the orbicularis and the fascia of the muscles that originate at the orbital rim to include the superior quadratus muscle medially and the zygomaticus major and minor, laterally. With aging, the orbital septum, particularly in the lower lid, and more specifically, in the lower third of the lower lid, becomes attenuated and stretches out. It is clear that the prominence of the orbital fat and lid convex contour is maximal in this attenuated region (Fig. 1).

SURGICAL CONSIDERATIONS

Questions in the medical history, which are specific to eyelid disease, relate to whether there is a history of epiphora, burning, and irritability to the eyes, particularly if wetting agent drops are used to deal with the symptoms. The epiphora that is evident with dry eye syndromes is a reflexive irritation rather than a sign of adequate moisture production. Specifically, patients with “dry eye syndrome” (Sjögren’s syndrome) are at greater risk for symptoms postoperatively with even minor degrees of incomplete eyelid closure. This would be particularly notable in the younger aged patient, that is, under 50 years of age. However, it may

also be a part of the normal aging process in which there is decreased tear production, as an individual grows older.

A major physical factor influencing surgical considerations for blepharoplasty of the lower lid is the prominence of the globe; that is, an excessively prominent globe due to malar hypoplasia, or soft-tissue proptosis, is more prone to postoperative ectropion, and “clotheslining” with the lateral canthal tightening. Patients who have lack of prominence of the malar eminence are more prone to developing ectropion postoperatively related to reduced support of the cheek tissue related to the lower lid. Contraction, laterally, in the orbital skin, particularly the orbital portion of the orbicularis muscle, will create prominent dynamic, wrinkle fold lines, or “crow’s feet.” Deemphasizing of the orbicularis muscle action in this area such as by Botox may give a more youthful appearance to this region, similar to the forehead musculature (15). A significant contributor to the appearance of “tiredness” is ptosis of the upper eyelid (10). Optimally, ptosis of the lid should be corrected when there is a malposition (inferior displacement) of the upper eyelid such that there is greater than 2mm overlap of the limbus by the upper eyelid free border.

Another important feature to note, related to the physical examination, is brow position. As noted before, the brow position has a significant influence on the eyelids, particularly related to upper eyelid skin redundancy. A depressed brow may result in in-folding of the upper eyelid skin and removal of the eyelid skin alone without appreciating the need for supporting the brow would only yield a further descent of the brow and a persistence of the redundancy of skin in the upper eyelid. Notation should be made of the symmetry or asymmetry of the brow and its curvature characteristics (16,17). As noted earlier, women, who have a youthful arch of the brow, have a high point at the junction between the medial two-thirds and lateral one-third of the brow (11,12). Male brows tend to be more horizontally oriented without a significant arch (18–20). These characteristics should be preserved or enhanced as per the patient’s wishes.

Protrusion of upper eyelid skin and fat should be noted, as well as the presence, absence, or accentuation of an upper eyelid crease. Typically, fat herniations are visible in the medial portion of the upper eyelid, and lacrimal gland prominence may be visible in the lateral portion. With significant descent of the lacrimal gland, this may also present beneath the eyelid in the conjunctiva. This observation will allow for correction of the malposition of the gland by a pexy procedure intraoperatively (21,22). Eyelid ptosis is a significant factor, influencing not only vision but also perception of youth and “wakefulness.” If there is significant redundancy of skin overlying the upper lid crease, this may mask a readily visible ptotic eyelid. Correction of the ptosis can be performed intraoperatively yielding an overall improved result aesthetically, as well as functionally (23–25). This correction may also influence forehead wrinkling, as the brows will not have to abnormally assist eyelid elevation when ptosis is corrected. Severely ptotic patients may have an exaggerated supratarsal crease due to attenuation and elongation of the levator aponeurosis attachment to the tarsus, leaving eyelid opening dependent on the attachment of the levator muscle to the skin (in the Caucasian patient). This exaggerated pull at the level of the supratarsal crease may also result in the appearance of hollowing of the eyes.

Care should be taken to evaluate the position of the medial and lateral canthi. Typically, the lateral canthus is at, or slightly (1–2 mm in Caucasians, African Americans, and Hispanics) above, the position of the medial palpebral fissure (26). This orientation is important particularly in dealing with laxity in the lower lid intraoperatively. Notation should be made of asymmetry of globe prominence. Knowledge of this asymmetry would require a modification of technique unilaterally in order to achieve a more symmetrical result from surgery, specifically related to positioning of the lateral canthus and skin resection of the lower lid. Lower lid tone should be assessed both medially and laterally to determine whether sufficient laxity exists so as to put the patient at increased risk for exposure keratopathy in the postoperative period. Pulling and releasing the lower lid skin to test tone is referred to as the “snap back test.” Assessment of adequacy of tear film is an important concept particularly in patients who have a history of excessive tearing or sensitivity to light and sun. This can be by history but may be documented by use of Schirmer’s test (27–29).

Notation of the contour of the lower lid and evidence of exposure keratopathy should be noted in the exam if present. Typically, fat herniation, when present, is evident particularly in the medial and inferior aspects of the lower lid, just above the orbital rim. Ordinarily, there is also a

depression in contour at the orbital rim and increased prominence of the malar soft tissue profile inferior to this. The “tear trough” develops in patients in their mid 40’s, with a progressive and more widespread descent of the midface soft tissue is evident in patients in their late 40’s to 50’s (30). Finally, notation should be made of the degree of soft-tissue edema or swelling in the lower lids inferiorly, particularly the “festoons” related to laxity or stretching of the orbicularis oculi muscle (31,32). This deformity is not corrected by “standard” blepharoplasty techniques but can be corrected by a separate tightening myoplasty/pexy procedure. Failure to address the need for this correction will yield a soft-tissue “bubble” at the level of the inferior orbital rim.

GENERAL

As in most conditions, both historical and physical examinations are necessary to judge a patient’s suitability for surgery. From a historical standpoint, general health condition should be evaluated, particularly related to cardiovascular status and pulmonary disease. Medications to these ailments sometimes also influence the suitability for surgery (particularly anticoagulants), antihypertensives, Vitamin E, and certain herbal medicines (33,34).

Other factors which may be influencing suitability for surgery relate to the presence or absence of thyroid disease (either hyper- or hypothyroid). Patients with thyroid disease tend to have retraction of the eyelids related to spasm of sympathetically innervated musculature in the upper and lower eyelids, and hypertrophy of muscles and soft tissues intraorbitally, which results in unusual globe prominence. The reason that is a concern is that any tightening of the lid, either medial laterally or superior inferiorly, is more than likely to exacerbate a globe protrusion (and therefore exposure) when compared to individuals without prominent globes (“clotheslining”). The canthopexy still may be done, but one must use less aggressive tightening, and also exhibit greater emphasis on lifting the lateral canthus more cephalad to cover the greater diameter of the globe. In patients with hypothyroidism, there is a tendency to have persistent lid edema for a prolonged time in the perioperative period (35).

Other concerns relate to history of progressive ptosis with visual obscuration, particularly associated with generalized weakness and fatigability, which may be an early sign of myasthenia gravis. Finally, a familial history of prominent eyes may indicate more common congenital diseases such as mild forms of Treacher Collins or Crouzon’s syndromes.

PERSING AND KNOLL SURGICAL TECHNIQUE

Anesthesia

Blepharoplasty surgery may be performed with the support of either local anesthesia, and sedation, or general anesthesia. The advantages of local anesthesia in performing this procedure are a quicker recovery, and the ability to have the patient open and close his/her eyes intraoperatively to judge lid position. In patients in whom eyelid ptosis correction is planned, local anesthesia with sedation is highly desirable. For patient comfort, however, a general anesthetic may be preferred by many.

Markings

With the patient in an upright position preoperatively, markings are made of areas of fatty prominence and depression in both the upper and lower eyelids. The advantage of having the patient in the upright position relates to change in fatty prominence when lying supine. It is desirable, but not necessary, to have the patient’s upper and lower lid incisions marked out in this position as the skin crease lines are usually well defined in the lower lid just at the lash border (subciliary or transconjunctivally), and in the upper eyelid, approximately 10 mm above the lash border at the mid portion of the pupil. Pinching the upper lid tissue to determine probable extent of removal is helpful, but not exact. If the eyebrow is to be elevated or stabilized by a pexy procedure, it would be better to simulate the elevation brow procedure in advance and then perform the pinch test. Usually, 1 mm of eye opening is sought to balance the goals of sufficient removal of redundant skin to achieve a well-defined upper lid crease, while simultaneously preserving sufficient skin laxity to close the lid adequately, postoperatively.

Upper Eyelids

In the upper eyelids, the first step is correction of the eyebrow position and contour deformity. As foreheadplasty is covered elsewhere, only stabilizing the position of the eyebrow from the upper eyelid incision will be presented in this chapter. After appropriate marking of the upper eyelid crease, and administration of local anesthetic, a submuscular preseptal dissection is performed to the superior orbital rim from approximately the superior medial canthus to the superior lateral canthus regions. In women, in particular, where brow contour is elevated at the junction of the medial two-thirds and lateral one-third of the orbital rim, dissection is continued above the orbital rim in an immediate supraperiosteal plane. Care is taken not to extend dissection into the overlying superficial musculature above the rim so as to avoid injury to the frontal branch of the facial nerve. At a point approximately 1.5 cm above the orbital rim, and the same distance from the midline bilaterally, the soft tissue in the subcutaneous plan just inferior to the brow is attached to the frontal bone periosteum. This attachment allows for appropriate eyebrow fixation and slight elevation of the brow (36).

A 2 to 3 mm elevation of the brow may be accomplished, but the main purpose of this maneuver is not elevation of the brow [a formal foreheadplasty (endoscopic or open) is more effective], but stabilization of it, so that with subsequent skin removal in the upper lid, it does not cause a descent of the brow resulting in folding of the upper eyelid skin again (Fig. 2). Following pexy of the brow bilaterally, reinspection of the orbital fat protrusion sites is performed. As described earlier, usually the orbital septum is visibly attenuated medially and inferiorly. A small resection of fat in this area with generous bipolar coagulation of the fatty soft tissue and the orbital septum in the region reduces the profile of the fat in this area, yet maintains intraorbital volume as much as possible. Inspection of the laterally situated lacrimal gland is also assessed to determine whether a pexy of the lacrimal gland is warranted. If so, the capsule is attached to the inner aspect of the periosteum in the orbital rim laterally. Before skin is resected, eyelid ptosis is corrected with stitches at the midpoint and symmetrical points, lateral and medial lid on the anterior superior tarsus with resorbable suture, unilaterally or bilaterally, as needed. The patient, although sedated, is asked to open and close his/her eyes to ensure that the degree of correction of the ptosis is appropriate. A slight overcorrection of 1 mm is typically needed. If the patient is being operated under general anesthesia, a more conservative plication of the levator aponeurosis is undertaken. Following this, skin resection is performed using, as the entry point, the incision line at the level of the supratarsal crease. The "pinch" test again guides appropriate resection amount. Although individual pathology varies, typically, in the upper outer quadrant, there is more likely to be redundant skin postoperatively with a pure "lens form" resection. Therefore, expansion outward to include a generous amount of resection in the lateral lid usually proves fruitful. Resection taking both orbicularis muscle and overlying skin is performed in order to further define this lateral crease, optimally.



FIGURE 2 Internal brow pexy to the frontal periosteum with a prolene suture. A 2 to 3 mm elevation of the lateral third of the eyebrow can be achieved, resulting in a more aesthetic, pleasing arch of the eyebrow.

Lower Lid

In the lower lid, there are more varieties of surgical approach to correct eyelid deformity. The simplest approach is the transconjunctival approach. This is typically done when no skin resection is warranted, there is no external scar accepted, when there is minimal evidence of descent of soft tissue in the upper cheek, or when concomitant laser treatment of the lids is planned. This is particularly the case in younger patients (30–40 years). Following injection of local anesthetic with epinephrine, an incision is made in the conjunctiva approximately 2 to 3 mm below the inferior tarsal border. A preseptal dissection is performed down to the orbital rim. Areas of attenuation of the orbital septum are defined and bipolar coagulation of the orbital septum to thicken and contract the septum without removal of fat is the simplest approach for very minor irregularities. On the other hand, if there has been some element of SOOF migration inferiorly, a small cuff of orbital rim musculature is elevated and an apron of fat is developed by cutting the inferior orbital septum and teasing out a small apron of fat (5–10 mm) (Fig. 3). Care is taken to avoid injury to the extraocular muscles, particularly inferior to the oblique muscle, which has its origin in the medial inferior aspect of the orbit. This fat is then draped into the trough that has been created by elevation of the orbital rim musculature (37).

The muscle fascia is attached to the orbital septum mediolaterally with continuous resorbable suture (Fig. 4). As the capsulo palpebral fascia has already been divided at the level of the inferior tarsus, closure by a single small gauge suture of resorbable cat gut can be placed at the conjunctival surface (Fig. 5). The advantage of this approach is that it is quick and simple. For the majority of patients, a subciliary approach is elected because it allows for more wide visualization of the orbital rim and also the ability to correct skin and muscle laxity in the lower lid more fully.

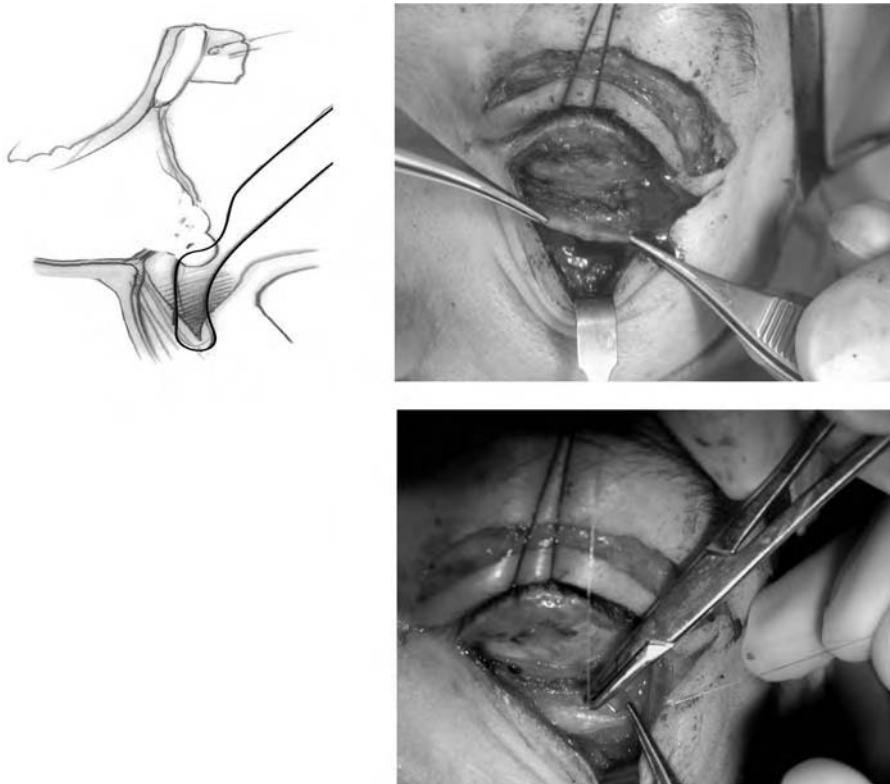


FIGURE 3 Depiction of the orbital septum release at the level of the infraorbital rim and the submuscular dissection of the subseptal fat “apron.” The “apron” will reach over the infraorbital rim like a “shade,” and is sutured into its new position within the submuscular pocket (SOOF). Reprinted with permission, *Plastic and Reconstructive Surgery*®.

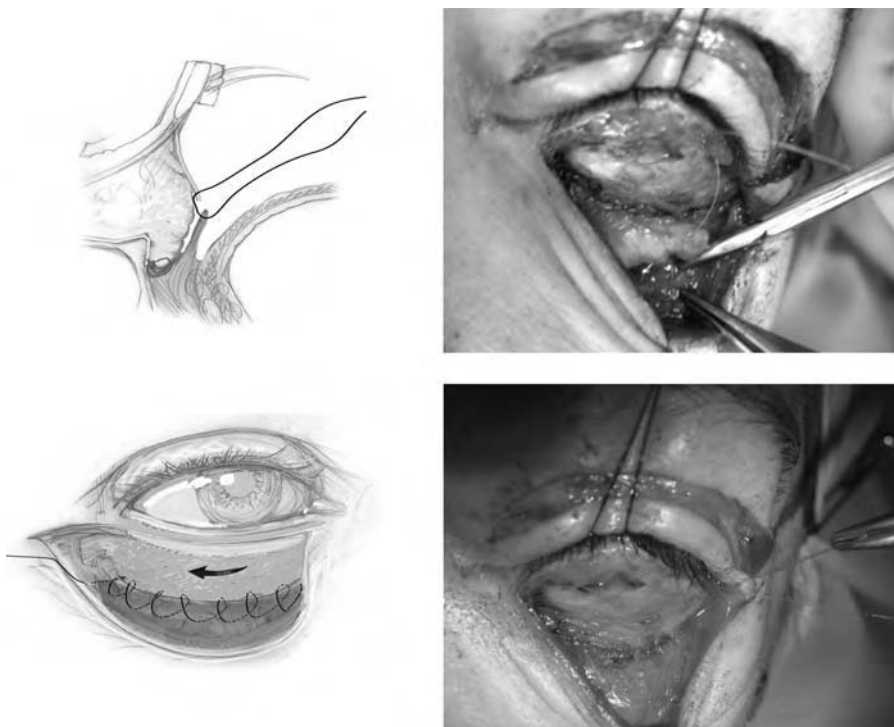


FIGURE 4 The leading edge of the muscle will be sutured to the orbital septum in order to achieve a smooth youthful appearing contour of the lower eyelid. Reprinted with permission, *Plastic and Reconstructive Surgery*®.

Following a subciliary lower lid incision, a subcutaneous dissection is performed above the pretarsal orbicularis muscle to the level of the septum at the inferior border of the tarsus. There, a submuscular dissection is performed preseptally to the orbital rim. Areas of attenuated orbital septum are noted. Typically located in the lower third to one-half of the eyelid, just above the orbital rim. An apron of fat is developed by cutting the orbital septum evenly just above the orbital rim. An incision is placed in the musculature at the inferior orbital rim, the superior quadratus, and the zygomaticus muscles. The trough, approximately 5 to 10 mm deep, is created, with care taken to avoid injury to the infraorbital nerve. The fat is placed in this pocket, or trough, and sutured with a continuous resorbable suture from the region of the medial canthus

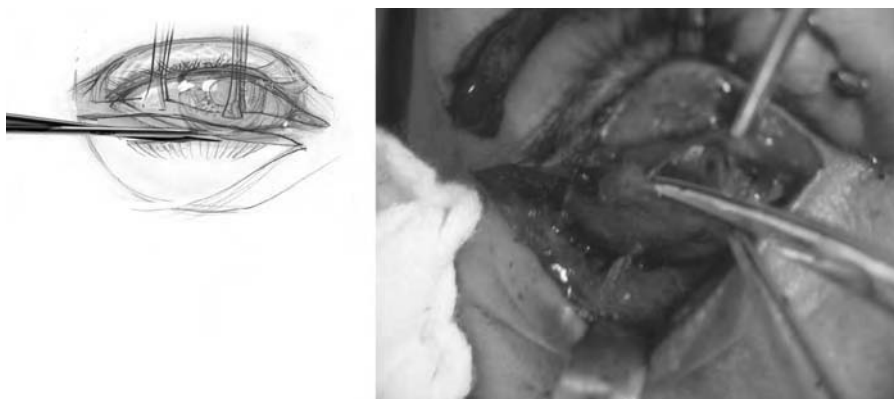


FIGURE 5 In order to avoid ectropion, the orbital septum and the capsulopalpebral fascia are divided at the level of the tarsus, followed by a canthopexy. Reprinted with permission, *Plastic and Reconstructive Surgery*®.

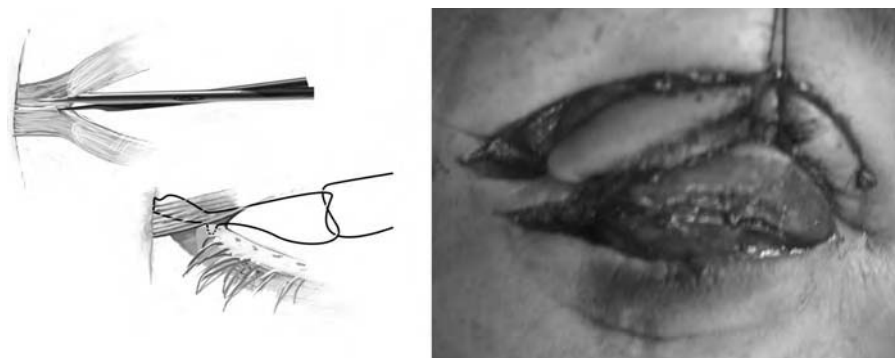


FIGURE 6 A lateral canthopexy is performed to avoid ectropion and to obtain a slightly upward slanting shape of the lower eyelid. Reprinted with permission, *Plastic and Reconstructive Surgery*®.

to the lateral canthus (Fig. 6). A second layer of closure is performed further cephalad in the orbital septum taking the leading edge of the developed cuff musculature to attach to the orbital septum in a location where the septum is of normal thickness and strength. The capsule palpebral fascia and the orbital septum are divided from the inferior border of the tarsus, leaving the conjunctiva intact, in order to prevent postoperative ectropion. Following this, assessment of the lateral canthus laxity is again made. If it appears as though there is a lax lower lid, a lateral canthopexy is performed (performed in approximately 90% of cases). This also gives an opportunity to elevate the lateral canthus and make more oblique the palpebral fissure if the patient so desires. If the patient has significant redundancy of lower lid tissue, particularly in a patient with senile ectropion, a lateral canthopexy alone may not be sufficient to support the lower lid. In this case, either resection of a portion of the lid (Kuhnt-Szymanowski procedure) or a lateral tarsal strip procedure (38) would be more appropriate. In the lateral tarsal strip procedure, a segment of the lateral aspect of the lower lid tarsus is denuded of overlying epithelium for a distance appropriate to the requirements for correction of the degree of laxity. This tissue is then used as a ligament, which can be attached to the infraorbital periosteum above the level of the lateral canthus. The lower lid tarsus is attached intraorbitally just superior to Whitnall's ligament, and tension is adjusted to achieve symmetry. Following this, inspection of the orbit and septal orbicularis is again performed. If laxity and redundancy of the muscle is appreciated, the orbicularis muscle is pulled superiolaterally and excess muscle trimmed at the level of the lateral canthus. Following this, the muscle is attached to the periosteum or fascia in the region of the lateral canthus. It should be noted that this muscle can be pulled too tightly particularly in patients with prominent globes resulting in an abnormal "clotheslining" of the lower lid contour.

Following this, skin excess is again assessed. Very little skin is actually removed in a superior inferior direction. It is pulled gently medial laterally and tissue is excised lateral to the lateral canthus. The incision line is confined only to the thin skin in the region of the lateral orbital rim and avoiding incisions lateral to it, so as to reduce scar visibility (Fig. 7).

Postoperative Care

The patient should be given minor and moderate analgesics to control any discomfort postoperatively. Ice applications to the eyelids and head elevation as well as the admonition to avoid heavy lifting and stress in the first 48 hours is appropriate. Typically, some form of wetting agent, either artificial tears or ophthalmic ointment, is useful in providing patient comfort. Swelling typically peaks approximately 48 hours after surgery and gradually abates over the course of the next two to three weeks. If dissection has been performed in the cheek to improve the contour at the orbital rim, an additional one to two weeks of swelling is frequently noted.

Complications

In order to manage postoperative complications, timely evaluation is appropriate. The most severe problem related to the eyes is loss of vision (39). However, this is an exceedingly rare



FIGURE 7 A 46-year-old female who underwent a bilateral lower blepharoplasty with the described technique. Of note, the postoperative youthful appearance of the lower periorbital area.

event and may be precipitated by massive retrobulbar anesthetic injection or hemorrhage. Hemorrhages are ordinarily less of a concern in patients undergoing blepharoplasty as retrobulbar injections are very infrequently performed (40,41).

However, postoperative nausea and vomiting are limited by antiemetics, and hypertension by antihypertensives in the perioperative period so as to lessen the likelihood of hemorrhage. The diagnosis of hemorrhage is evident by excessive lid and globe prominence and ecchymosis particularly if it is significantly asymmetric. Management of postoperative hemorrhage is immediate release of any constraining sutures, such as lateral canthopexy, and even division of the lateral palpebral fissure at the bedside. While this is being done, diamox and mannitol are given to lessen intraocular pressure. Immediate consultation with an ophthalmology colleague is appropriate. Evacuation of the hematoma would be performed as soon as possible.

Infection is a rare complication of blepharoplasty as the vascularity in the region is so abundant (42,43). Use of perioperative antibiotics may be of some benefit, but that has not been determined definitively.

The most concerning postoperative complication relates to exposure keratopathy (44). In the postoperative period, ectropion may be evident due to clotheslining of a prominent globe, excess skin resection, scarring or limitation of motion of the lower lid related to imbrication, restriction, or tying of the orbital septum or the capsule palpebral fascia. Facial muscle (pretarsal orbicularis) paralysis may also occur, but because of dual innervation (buccal branch medially and zygomatic branch laterally), this is an infrequent finding.

The management of ectropion, if it is relatively mild, is wetting agents (eye drops and ointments), and reassurance. Typically, in the first two to three weeks, there is a higher risk for lower lid malposition, and as long as it is relatively minor, there is no previous history of dry eye, and the patient is not symptomatic, this can be watched expectantly. On the other hand, if the patient's ectropion is related to unusual tethering of the lower lid (e.g., clotheslining), this needs to be released operatively. If it is related to skin resection, either local flaps or skin grafts may be necessary to correct the problem. However, the timing of this is delayed if the patient's symptoms/signs allow.

The most troublesome postoperative complication is not achieving the results that you and/or the patient wish. Asymmetry, persistent skin folding, absence of wrinkle removal, or even pigment changes in the lower lid may be the source of concern. These problems can be addressed in a more deliberate fashion as it is appropriate to wait at least a few months, preferably six months, before any further revision is undertaken (depending on the degree of severity and the patient's concern). Earlier operative intervention may result in operating on an immature scar bed with changing soft-tissue profiles leading to an inferior end result.

Secondary Blepharoplasty

Secondary blepharoplasty in the lower lids is often done to either correct infraorbital rim depression deformities which were not corrected at an earlier operative procedure, or for prominent fat, scarring, or skin resection asymmetry. These should be addressed with the

understanding that less tissue is going to be resected, and ectropion is more likely to occur postoperatively (45,46). Overresection of orbital fat may yield an enophthalmic appearing globe (disappearing eyes). This is best managed by volume enhancement such as can be achieved with orbital floor implants. In the upper eyelids, related to the possible need for stabilizing the brow through a more formal upper brow stabilization, an endoscopic or open coronal lift foreheadplasty may be performed. Eyelid ptosis not well recognized preoperatively is frequently more evident postoperatively. Surgical correction with a local/sedation anesthesia approach is more likely to achieve the precision in lid function desired.

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16 Cheek Reconstruction: Regional and Microvascular Free-Tissue Transfer

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INTRODUCTION

Cheek defects result from multiple etiologies including cutaneous neoplasm, trauma, burn injuries, and congenital pathology. The cheek represents a significant percentage of facial surface area making appropriate coverage of the defect essential to the restoration of overall facial aesthetics. Reconstructive options include a wide spectrum of techniques from elliptical excision followed by simple primary closure, skin grafts, and local flaps, to distant flaps and free-tissue transfers for more extensive defects.

Surgical reconstruction of cheek defects can be technically challenging. Large cheek and lower eyelid defects are particularly difficult reconstructive problems given their intimate association with critical surrounding facial anatomy and the potential for long-term pitfalls. The repair must achieve appropriate soft-tissue replacement and restore contour while minimizing distortion of the surrounding anatomy including scalp, eyelid, nose, or lips. Meticulous preoperative evaluation must be performed in order to identify the most appropriate technique for treatment and to avoid complications such as flap necrosis and donor site morbidity.

ANATOMY

The concept of aesthetic subunits has been previously introduced and is frequently utilized in considering various options for cheek reconstruction. Three overlapping zones of the cheek aesthetic unit include the suborbital zone, preauricular zone, and buccomandibular zone (1) (Fig. 1). The suborbital zone is bordered by the nasolabial fold medially, the anterior sideburn laterally, the lower eyelid superiorly, and the gingival sulcus inferiorly. The preauricular zone comprises the lateral cheek component and extends from the malar eminence medially to the junction of the helix and cheek laterally and down to the mandible inferiorly. The buccomandibular zone consists of the lower cheek region inferior to the suborbital zone and anterior to the preauricular zone including the oral lining. Defects in all three zones can be addressed by local flaps, regional flaps, or distant flaps. Buccomandibular zone defects may require reconstruction with a combination of flaps in order to provide coverage for both external skin and the oral lining.

The blood supply of the cheek is well arborized and permits a variety of local flap designs for reconstruction (Fig. 2). The primary arterial supply to the cheek comes from the external carotid artery with contributions from the internal carotid system. The facial artery, the dominant source of blood supply to the cheek, traverses the face obliquely from anterior to the mandibular angle and terminates in the angular artery. The transverse facial artery originates from the superficial temporal artery and also contributes to the facial vascular supply.

EVALUATION

Most cutaneous malignancies of the face can be treated with simple excisions and primary closure without leading to significant aesthetic compromise. However, more extensive defects that require tissue replacement warrant careful evaluation in order to choose a reconstructive technique that will provide the best cosmetic outcome. Reconstructive choices for the cheek depend on multiple factors including defect size, depth, shape, and site. In general, most cheek defects greater than 30% of the cheek unit will necessitate recruitment of residual cheek and surrounding skin as rotational or advancement flaps (2). Large or deep defects that require

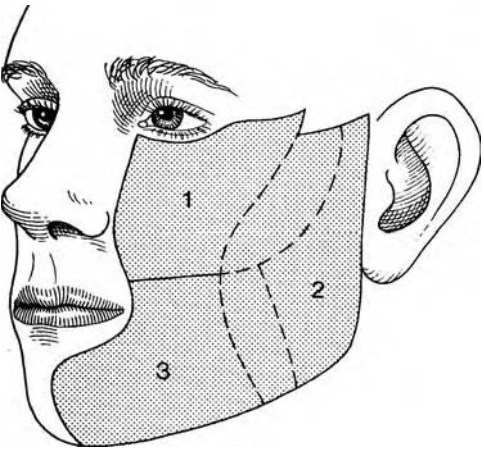


FIGURE 1 Three zones of the cheek aesthetic subunit. (1) suborbital zone, (2) preauricular zone, and (3) buccoman-dibular zone. *Source:* From Ref. 1.

extensive skin coverage or bulk are often treated with distant tissue by microvascular transfer. Full thickness cheek defects including the intraoral lining may require reconstruction with an additional flap. The site of the defect is the predominant factor determining flap design. Small to moderate anterior cheek defects can be effectively treated with laterally based rotation advancement flaps, while posterior or large anterior defects are repaired with medially based rotation advancement flaps (2). In addition, the position of surrounding anatomic landmarks, such as the eyelid, nose, lips, or scalp, is extremely important in the overall facial aesthetic outcome and should be preserved at all costs.

TREATMENT

Local Flaps

Most small cutaneous malignancies of the face can be treated by resection and primary closure, ideally along relaxed skin tension lines. Small defects of the cheek that are not amenable to primary closure can frequently be reconstructed with small local flaps, taking advantage of the laxity and vascularity of the surrounding facial skin. Various areas of the cheek provide a generous source of tissue for reconstructing a wide variety of defects, and well-designed local flaps can provide excellent color, texture, and contour match to the defect.

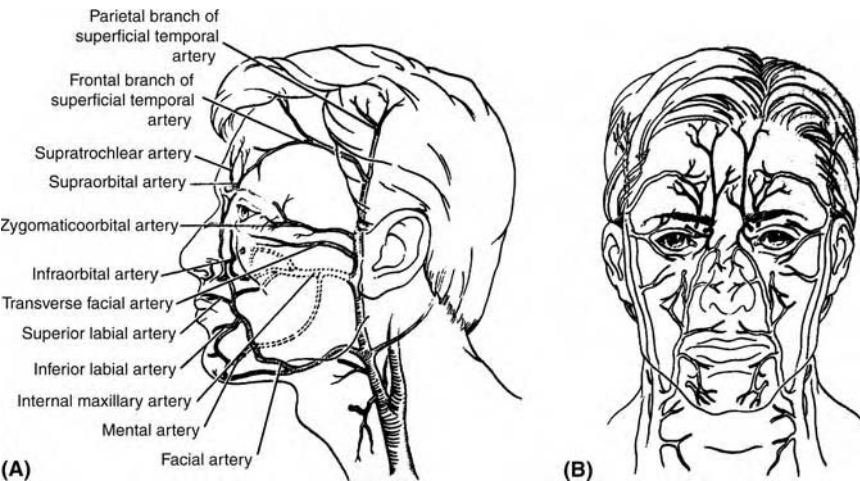


FIGURE 2 Vascular anatomy of the cheek. *Source:* From Ref. 48.

Rhomboid Flaps

Small defects that are not amenable to primary closure can be managed by local flaps such as a rhomboid flap. Rhomboid or modified rhomboid flaps are simple techniques that utilize the surrounding soft tissue to provide coverage for small cheek defects. There are multiple possible flap designs for any given defect. However, even when care is taken to place the donor scar along relaxed skin tension lines, most scars from rhomboid flaps tend to lie prominently in an unfavorable orientation and result in cosmetically poor outcome.

V-Y Flaps

The V-Y advancement flap technique is an effective way of closing small defects in the head and neck regions (3). This local flap option transfers an island of skin immediately adjacent to the defect to provide soft-tissue coverage based on a subcutaneous vascular pedicle (Fig. 3). The cheek is anatomically well suited for this reconstructive option given the laxity and abundance of subcutaneous tissue facilitating flap mobility. Modifications of the traditional V-Y advancement flaps have also been described for reconstruction of even larger facial defects or those located in areas with less subcutaneous tissue (4–6). For example, the extended V-Y flap involves adding an extension limb onto the advancing edge of the traditional V-Y flap and has been used effectively for reconstructing areas with less tissue mobility (4). The V-Y advancement flap can generally provide a well-contoured reconstruction with excellent skin color and texture match for small cheek defects.

Skin Grafts

Skin grafts, split- or full-thickness, in general provide disappointing aesthetic results despite the ease and simplicity of performing the procedure. The color, texture, and contour match are suboptimal and unpredictable and frequently lead to a patch-like appearance. Split-thickness skin grafts will eventually contract and can cause malpositioning of surrounding anatomic structures, such as the lower eyelid or the oral commissures. Even full-thickness skin grafts generally are not able to provide sufficient thickness to adequately address the skin and the subcutaneous tissue defect created by most resections. Therefore, the role of skin grafts in cheek



FIGURE 3 V-Y flap. (A) Preoperative design of a V-Y advancement flap for coverage of the right cheek defect after planned tumor resection. (B) Postoperative result after the V-Y advancement flap.

reconstruction should be minimal beyond temporary coverage of the defect or facilitating closure of the donor site when large flaps are being used.

Tissue Expansion

Larger deformities of the cheek can be reconstructed using tissue expansion alone or in combination with other techniques. By expanding the neighboring facial skin, tissue expansion provides the best color and texture match for facial reconstruction (7–9). Careful preoperative planning including expander selection as well as location of expander and port pockets is important in achieving successful reconstruction (10). Incisions for expander placement should be minimal in length and located away from the defect or the lesion to be excised. Location of the incision should also take into consideration the potential design of the future flap in order to ensure flap vascularity as well as to optimize defect coverage. Expander width and length should be at least as large as the defect, and intraoperative filling of the expander can reduce hematoma and seroma formation (10). Expanders are typically filled once a week for 6–8 weeks and overexpanded by 30% to 50% until the final reconstruction can be performed. At the time of final reconstruction with advancement flaps using expanded donor site tissue, performing a capsulotomy increases the surface area of the expanded and can facilitate coverage.

Successful reconstruction of the cheek has been reported with tissue expanders placed superficial to the superficial muscular aponeurotic system (SMAS)/platysma layer over the mandibular angle and body followed by a cervicofacial flap using the expanded tissue (7). Nonetheless, complications with tissue expansion in head and neck reconstruction are not rare. The highest incidence of complications appears to occur in the cheek and neck region with implant exposure being the most common complication (11). Despite such complications, with careful planning at each stage of the procedure the final reconstructive result using the expanded flap technique is usually satisfactory.

Cervicofacial Flap

The cervicofacial rotation-advancement flap has been traditionally advocated for use in reconstruction of defects of the cheek and lower eyelid region (12–14). Frequently used for medium- to large-size defects, the cervicofacial flap provides tissue with excellent color and texture match by recruiting the neighboring cervical cheek and subauricular skin adjacent to the defect. With adequate cervical skin laxity, the donor site can primarily be closed with ease and good cosmetic appearance. The traditional cervicofacial flap is medially and inferiorly based and is useful for more posterior cheek defects. The reversed cervicofacial flap is a laterally and inferiorly based advancement flap, which is useful for anterior cheek defects.

A standard cervicofacial rotation-advancement flap incision originates from the superolateral aspect of the defect, extends around the posterior cheek following the sideburn, inferiorly along the preauricular crease, and then around the earlobe and the occipital hairline. The flap is dissected in the subcutaneous tissue plane and the residual cheek and cervical skin is advanced medially to cover the defect. Superior dissection of the flap lateral to the eye is important in order to avoid ectropion as the flap is advanced. Any redundant skin created medially after advancement can be excised within the nasolabial fold. The subauricular and neck tissue is advanced superiorly to close the donor site. The medial vascular base for the flap is supplied by the facial and submental arteries. One of the main problems with the cervicofacial advancement flap has been distal flap necrosis, especially in smokers. A modification can be made to improve flap vascularity by performing flap elevation through the deep plane below the SMAS and platysma muscle (15). Deep plane dissection increases flap reliability and permits more mobility for larger cheek defect reconstructions.

Most recently, Boutros and Zide described a modified angle rotation flap for cheek and eyelid reconstruction (16). The flap design is an anteriorly and inferiorly based large bilobed flap. It involves the entire cheek and preauricular tissue transposed to the cheek or lower lid defect as the first flap, and the angle rotation flap from the subauricular region is rotated upward and medially as the second flap to close the donor site. The medial and upward rotation advancement allows significant mobilization of abundant posterior soft tissue into the cheek defect and lower eyelid (Fig. 4). In addition, the angle rotation flap eliminates the need

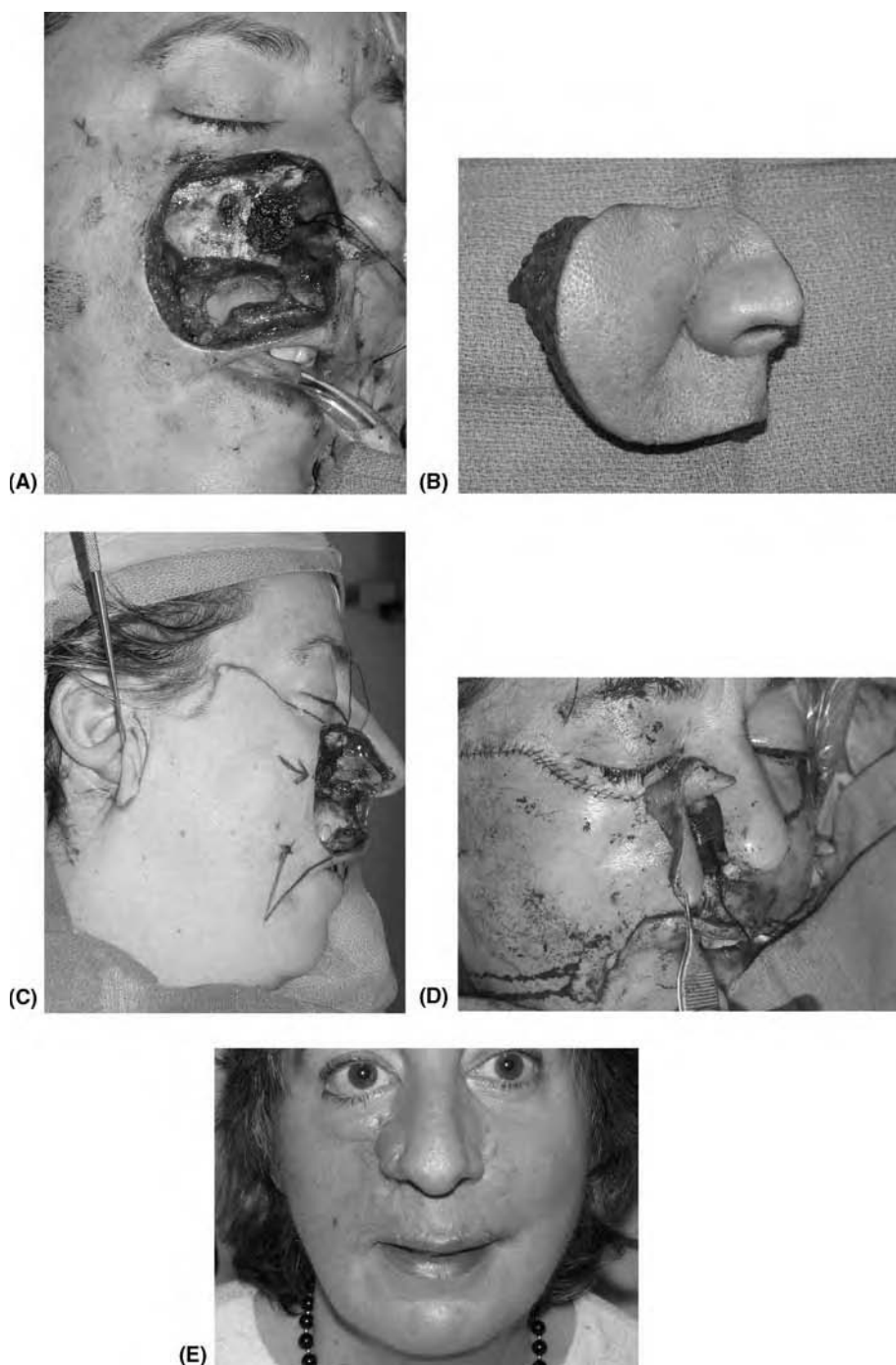


FIGURE 4 Cervicofacial flap. A 52-year-old woman who underwent a wide resection of spindle-cell sarcoma involving the right cheek, nose, and upper lip. (A) Defect after excision. (B) Resected tissue specimen. (C) Cervicofacial flap design. (D) The redundant superior portion of the flap was split and turned inward to reconstruct the nasal lining. (E) Three-month postoperative result after debulking of the flap.

for extending the flap down into the neck, as seen in standard cervicofacial flaps, thus limiting donor site scarring and achieving a better cosmetic result. Moreover, the flap design allows for future readvancement in the event of further cheek defect coverage needs.

The medially based cervicofacial flap can also be extended as a cervicopectoral flap in order to provide coverage for larger cheek defects (17,18). This flap recruits the chest skin in addition to neck skin by extending the incision down into the anterior chest, passing 2 to 3 cm above the nipple-areola complex to the parasternal region. The cervicopectoral flap is vascularized by anterior thoracic perforators off the internal mammary artery and is elevated deep into the platysma muscle and anterior pectoral fascia. The cervicopectoral advancement flap can cover large cheek defects of up to 6 to 10 cm without significant donor site deformity.

The laterally based or reversed cervicofacial advancement flap is an effective way to reconstruct anterior or medial cheek defects, including the nasal sidewall and lower medial periorbital region (2,19). The incision for the reversed cervicofacial flap generally starts from the defect, follows the nasolabial fold past the oral commissure, and the submental fold. The flap recruits the excess tissue from the lower aspect of the face, including the jaw and the submental tissue, and transfers it superiorly into the perioral cheek region. The laterally based cervicofacial flap has two main vascular supplies: (i) branches of the facial artery, which supply most of the flap, and (ii) the transverse facial artery, which originates from the superficial temporal artery supplies the superior aspect of the flap. Similar to the medially based cervicofacial advancement flap, the laterally based flap incision can also be extended inferiorly into the sternum and across the chest to the axilla as a cervicopectoral flap in order to provide coverage for larger defects (20).

Submental Flap

The submental artery island flap was first described by Martin and can provide a large, pliable cervical skin paddle for cheek reconstruction (21). This flap is supplied by the submental arterial branch of the facial artery. Anatomic studies have shown that the submental artery has the diameter of approximately 1.2–1.7 mm and has a long pedicle length of 50–60 mm (22). This long pedicle allows for a wide arc of rotation and significant mobility of the submental artery island flap. Venous drainage of the submental flap is through the submental vein into the anterior facial vein, and then into the common facial vein.

The flap is designed as an elliptical skin paddle in the submental region traversing the midline. Acceptable flap dimensions are from 5 × 5 cm to a maximum of 15 × 7 cm maximum to ensure vascularity (21,23). The skin paddle borders the mandibular arch superiorly and both mandibular angles laterally. The flap is harvested along with the platysma muscle from the contralateral to ipsilateral pedicle side after ligation of the contralateral submental vessels. Once the submental flap with the pedicle has been dissected from the surrounding tissue, the flap can be mobilized and tunneled to the recipient site for reconstruction. The donor site is closed primarily and the resultant linear scar is well concealed within the submandibular region (Fig. 5).

The submental flap has also been used as a functional flap by maintaining the innervation to the platysma muscle (24) (Fig. 5). The cervical branches of the facial nerve are kept with the flap during the flap elevation. Once the flap is transposed onto the cheek defect, the platysma muscle fibers are rotated to provide an upward pull on the oral commissure to assist with facial animation. The innervated platysma musculocutaneous flap, thus, is an effective way to augment facial animation while providing appropriate soft tissue for moderate-size, full-thickness cheek defects.

The submental flap is a simple and yet versatile regional flap that can be utilized for reconstruction of large defects of the cheek. It provides an excellent color and texture match for facial reconstruction with minimal donor site morbidity. The thin and pliable quality of the skin paddle permits ease of reconstruction throughout nearly the entire ipsilateral face as well as the oral cavity. In addition, cosmetic improvement can be achieved, especially in older patients, by removal of excess submental tissue.

Pectoralis Flap

The pectoralis myocutaneous flap was first described by Ariyan in 1979 and is one of the most versatile distant pedicled flap options, providing coverage for not only sternal, oropharyngeal,

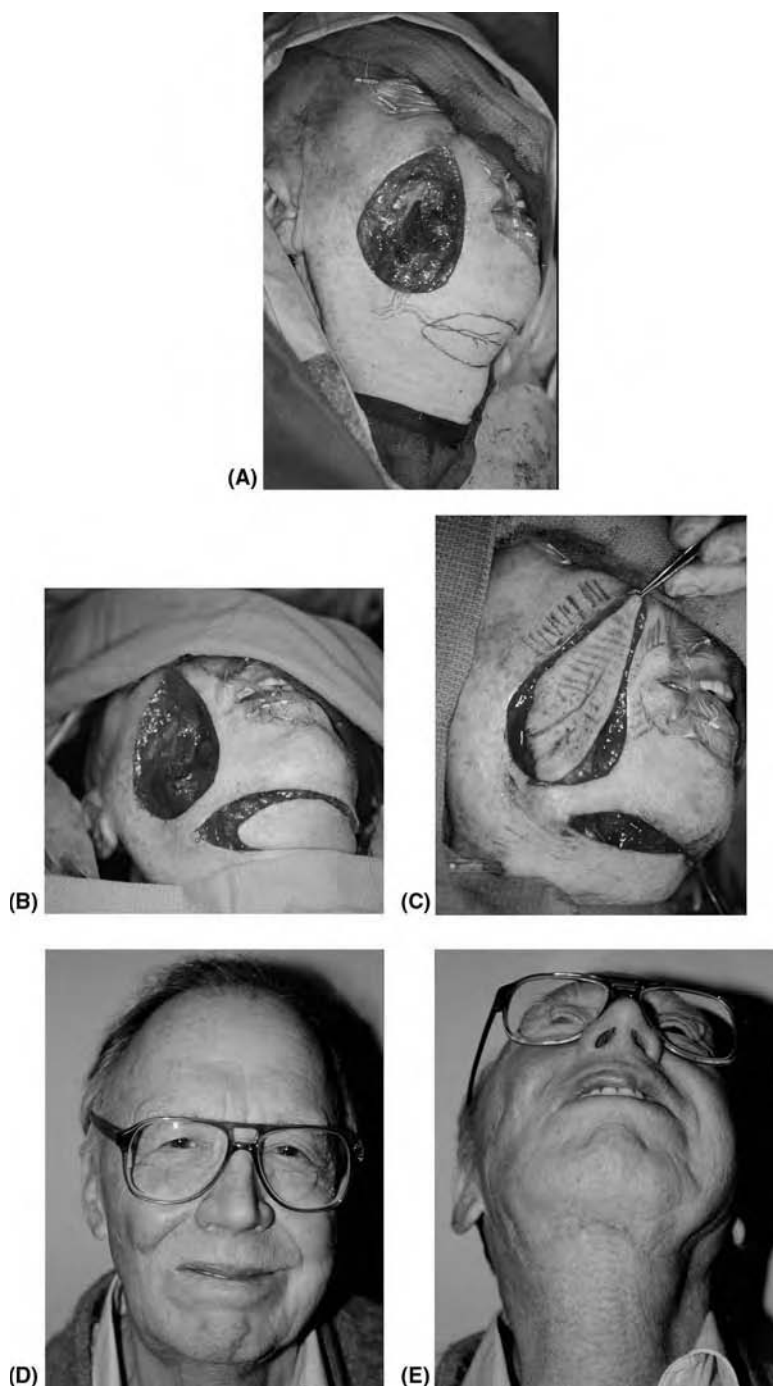


FIGURE 5 Functional submental flap. (A) Full-thickness cheek defect after excision of right-cheek, squamous-cell carcinoma involving the muscles of facial expression. (B) Submental flap incised. (C) Flap transposed into cheek defect. (D) Postoperative view with restoration of contour and function. (E) Postoperative view showing minimal donor defect.

or mandibular reconstructions, but also for soft-tissue defects of the face (25). The pectoralis major muscle originates from the medial half of the clavicle, sternum, and upper seven ribs, and inserts into the humerus. The dominant vascular pedicle is the thoracoacromial artery, which enters the muscle on its deep surface at the junction of the middle and lateral one-third of the clavicle. The flap can be utilized to reconstruct external facial defects as well as the intraoral lining. After elevation, the pectoralis myocutaneous flap can be rotated to 180° if a skin island is designed for reconstruction of the external facial defect, or rotated and flipped over if the skin island is to be used for the coverage of the intraoral lining. The donor site can be closed primarily if the size of the skin paddle is small, otherwise, skin grafting may be necessary. Release of the muscle fibers and dissection around the vascular pedicle will increase flap mobility and rotational arc to facilitate transfer to the cheek region. Successful facial reconstruction has been achieved with evidence of pectoralis muscle reinnervation following suturing the pectoral nerve to a buccal branch of the facial nerve (26). Pectoralis myocutaneous flap is a reliable reconstructive option for large defects of the cheek or head and neck region, especially when concomitant systemic medical problems or advanced disease makes the option of free-tissue transfer less than ideal.

Trapezius Flap

The trapezius myocutaneous flap is another distant pedicled flap option that can be used for facial reconstruction, especially for more posteriorly located facial defects. Various types of trapezius flap have been previously described, including the superior, the lateral island, the posterior island, the vertical, and extended vertical flaps (27–30). The trapezius muscle originates from the occipital bone and the spinous processes of the seventh cervical through 12th thoracic vertebrae and inserts into the scapula, acromion, and clavicle. The blood supply is from the transverse cervical artery arising from the thyrocervical trunk or rarely, the subclavian artery. The flap can be designed as an island flap from the lower trapezius muscle or as a vertical flap designed along the course of the transverse cervical artery. The superior fibers of the trapezius muscle can be left intact in order to prevent functional deficit (31). The trapezius flap offers acceptable replacement tissue for facial reconstruction and adequate tissue bulk; however, it offers poor color match and can have thick dermis which may not be ideal for the face.

The extended vertical trapezius flap has been described for difficult head and neck reconstructions (30). It is designed as a long vertical flap along the route of the transverse cervical artery. With its wide arc of rotation, the distal portion of the flap can easily reach the cheek region without much tension, and the donor site can be closed primarily. However, the extended vertical trapezius flap requires a second-stage procedure for division of pedicle.

The trapezius myocutaneous flap can be a good reconstructive option for posteriorly located defects of the head and neck or as a salvage procedure, especially when free-tissue transfer may not be an option.

Supraclavicular Flap

The supraclavicular area is considered one of the desired donor sites for facial reconstruction given its good color and texture match to facial skin. In order to utilize this anatomic region for facial resurfacing, a prefabricated supraclavicular flap has previously been developed by implanting a vascular pedicle underneath the flap (32). A tissue expander was also placed beneath the prefabricated skin flap to thin and increase the available donor skin surface area. More recently, the expanded supraclavicular fasciocutaneous flap has been successfully used in facial reconstruction even without the need for a prefabricated vascular pedicle (33,34). The supraclavicular flap is an axial flap based on the supraclavicular artery, a branch of the transverse cervical artery, and its accompanying veins. The expanded supraclavicular island flap involves placing a tissue expander under the supraclavicular flap area as the first-stage procedure. After expansion, the tissue expanders are removed and the expanded fasciocutaneous flap is then raised to cover the facial defect during the second stage. The donor site is primarily closed using ventral and dorsal advancement flaps. The expanded supraclavicular

flap has been effectively utilized in reconstruction of the face, including the cheek and the neck, and is a reliable treatment option especially for postburn patients who require extensive facial resurfacing.

Free-Tissue Transfers

Even though distant pedicled flaps can provide a dependable reconstructive option for large defects of the face, the cosmetic outcome is usually inferior to results from free-tissue transfer. Microvascular surgery, although technically challenging, has dramatically expanded the reconstructive possibilities in facial reconstruction. Microvascular free flaps can provide a large amount of distant tissue for reconstruction with unlimited mobility and less donor site morbidity and can potentially be performed as a single-stage procedure. Both complex facial defects that require judicious contouring and full-thickness defects that require composite tissue transfer can be successfully treated with free flaps. In addition, more recent sophisticated techniques of flap prefabrication and prelamination can be successfully incorporated in difficult facial reconstructions using microvascular surgery.

Microvascular transfer of a “folded flap” is an effective way to reconstruct full-thickness defects of the cheek. The radial forearm flap and the rectus abdominis myocutaneous flap are two folded free flaps that have been successfully used in complex full-thickness facial defects. The radial forearm flap, based on the radial artery and vena comitante vascular pedicle, can be designed with two skin islands connected by deepithelialized skin and folded on itself to simultaneously reconstruct the external cheek skin and the intraoral lining (35,36). The flap can be harvested along with a vascularized palmaris longus tendon, which can be used to suspend the flap for support (37). The rectus abdominis myocutaneous flap, based on the deep inferior epigastric pedicle, can similarly be designed with multiple skin islands in order to reconstruct multiple cutaneous and mucosal surfaces in complex facial defects. It can provide a large epithelial surface area as well as soft-tissue bulk that may be required in cases such as maxillectomy defects or base of skull tumor resections (Fig. 6). Reconstruction with folded flaps involves more than simply providing replacement tissue and necessitates careful preoperative and intraoperative planning. A three-dimensional defect must be converted into a two-dimensional pattern to design the most optimal folded free flap. In order to facilitate this conversion, Pribaz et al. have reported creating an intraoperative alginate moulage for the three-dimensional model of the defect, and then wrapping it with an Esmarch bandage to determine the locations and sizes of the epithelial surfaces required for the final reconstruction (38) (Figs. 6 and 9).

The anterolateral thigh flap is another potential donor site for free flap reconstruction of the cheek. This flap can be harvested as a fasciocutaneous flap or along with a portion of the vastus lateralis muscle based on the descending branch of the lateral femoral circumflex pedicle. The anterolateral thigh flap is more appropriate for laterally located cheek defects given the need for more soft-tissue bulk in this anatomic region. The flap can also be thinned to provide more aesthetic facial contour. For full-thickness cheek defects involving the oral commissure, restoration of oral competence in addition to replacement of soft tissue is a more comprehensive reconstructive goal (39,40). Recently, chimeric flaps from the lateral femoral circumflex system have been successfully used in reconstructing full-thickness cheek defects while simultaneously restoring oral competence through use of the tensor fasciae latae to suspend the oral commissure. The technique involves designing skin paddles that are individually supplied by separate perforator systems but joined more proximally in a single pedicle. Although technically challenging and offers suboptimal color match to the face, it provides more aesthetic three-dimensional reconstruction with good contour match (39).

Some ablative surgeries of the head and neck may involve resection of the mandible and require bony reconstruction. For cheek defects involving the bone, a fibula osteocutaneous flap is a good reconstructive option. The skin island can be designed so that both the external skin of the defect and the intraoral lining can be reconstructed. In extensive composite mandibular defects, a combination of free flaps may be necessary. For instance, the fibular osteocutaneous flap can be used to reconstruct the intraoral lining and the bony defect, and the anterolateral thigh flap can be utilized for external soft-tissue volume (41).

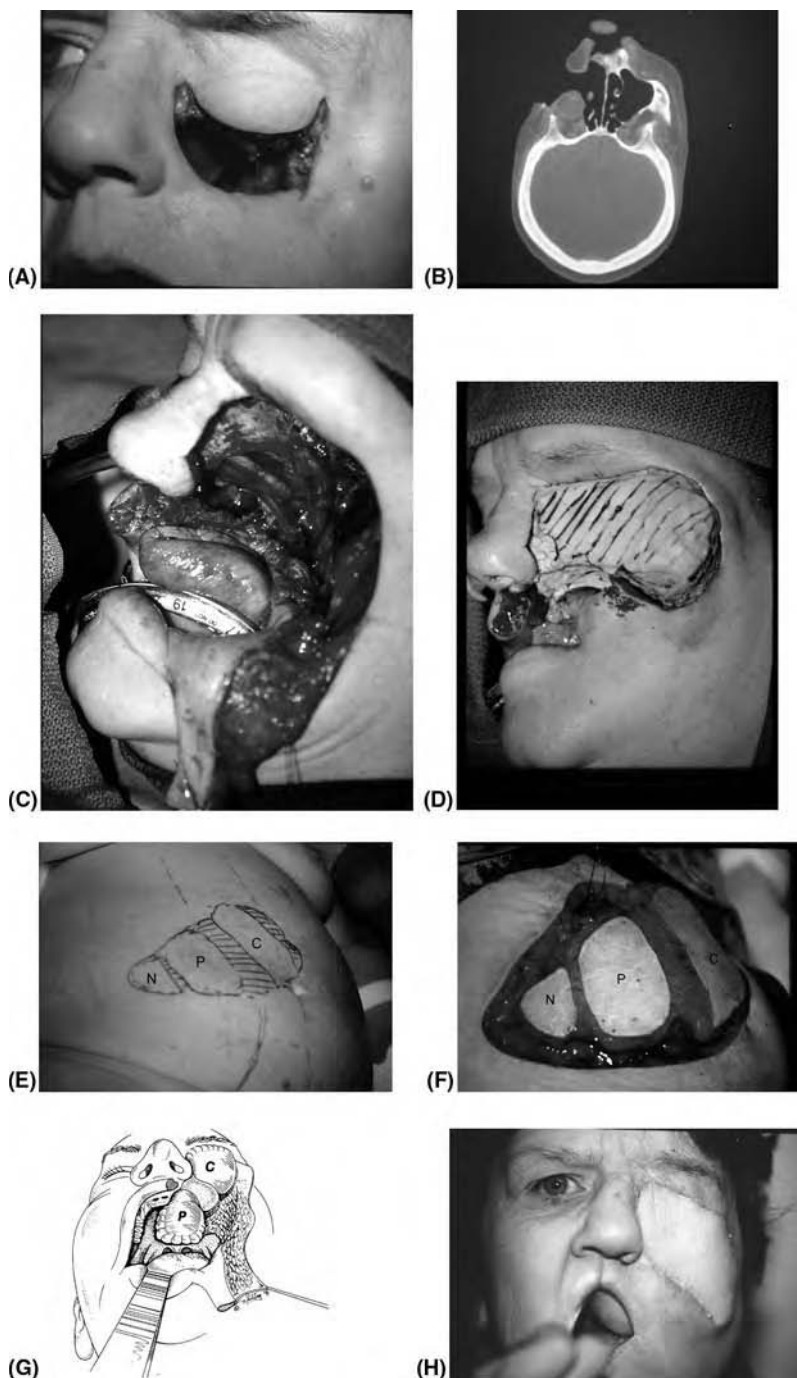


FIGURE 6 Folded flap, rectus abdominis. (A) A 53-year-old woman with long-standing squamous cell carcinoma of maxillary antrum with erosion forming an oronasocutaneous fistula. (B) Coronal CT scan demonstrating oronasocutaneous fistula. (C) Intraoperative photograph after orbital exenteration and left cheek with discontinuity resection of left nasal cavity, nasal septum, hemimaxilla, and most of palate. (D) Alginate mold in place, epithelial surfaces marked. (E) Two-dimensional flap marked from three-dimensional model of defect in most appropriate orientation on abdomen. (F) The flap is raised and de-epithelialized in situ to provide three epithelial surfaces for reconstruction of nasopharynx (N), palate (P), and cheek (C). (G) Inset of palate and cheek. (H) Three months postoperatively, showing a well-healed, functional, and aesthetically acceptable reconstruction.

FLAP PREFABRICATION AND PRELAMINATION

Both flap prefabrication and flap prelamination are two-stage procedures that provide useful adjuncts to reconstructive options for difficult head and neck defects, especially when available donor sites are limited. Flap prefabrication refers to a technique in which a vascular pedicle is transposed into a body of donor tissue. After neovascularization has taken place, the tissue is transferred based on its implanted vascular pedicle during a second-stage procedure (42,43). Flap prefabrication has been effectively utilized in facial burn reconstruction. Facial reconstruction for cheek defects resulting from excision of burn scar or release of contractures can be performed utilizing prefabricated flaps from the surrounding tissue, such as the neck, postauricular, supraclavicular, and scalp regions. A local vascular pedicle such as the superficial temporal pedicle can be transferred along with the temporoparietal fascia to the upper cervical area as the first-stage procedure for flap prefabrication (Fig. 7). After a maturation period of at least eight weeks, the prefabricated flap from the cervical region can then be transferred to reconstruct the cheek defect. Frequently, a tissue expander is placed below the vascular pedicle as well as the tissue to be prefabricated during the first-stage procedure. This step serves to thin and delay the flap as well as to facilitate the closure of the donor site. If no local vascular pedicle is available, as may be the case in severe burn patients, a distant vascular pedicle of reasonable length, such as the descending branch of the lateral femoral circumflex vessel, has been transferred as a “mini free flap” to create the necessary prefabricated flap (42). Similarly, cheek reconstruction using an expanded prefabricated musculocutaneous flap from the anterior chest with a pedicled serratus anterior muscle has been reported with good aesthetic outcome (44).

Flap prelamination involves creating a multilayered flap for a composite reconstruction by implanting selected tissue layers into an established native vascular bed. The second-stage procedure entails transferring the composite flap based on the native axial blood supply for reconstruction (45). Prelaminated flaps are useful in complex central facial defects resulting from trauma, burns, or radical resection of tumor, which involve the loss of the nasal structure and the lip (46). This reconstructive concept is applicable to the cheek reconstruction since many central facial defects frequently extend to include the surrounding cheek region making the soft-tissue requirement more challenging.

As a multilayered flap, a prelaminated flap can provide the lining, support, and the soft-tissue coverage necessary in complex central facial defects. Forearm, the most commonly used donor site for prelamination, has thin and pliable skin coverage appropriate for facial reconstruction. By implanting skin and cartilage grafts into its reliable vascular territory, a multilayered, three-dimensional prelaminated flap can be designed for complex nasal, cheek, and labial reconstruction (Fig. 8). Final reconstruction usually requires multi-staged procedures to separate the nose, cheek, and lip subunits and to refine the contour of each individual anatomic structure. Thus, as with most free flaps, the optimal reconstructive outcome for complex facial defects usually necessitate a combination of techniques where the initial free flap is followed by a second-stage local flap procedure for a more aesthetic final result. Figure 9 illustrates a complex facial defect case where various modalities of reconstruction were performed sequentially to maximize overall functional and aesthetic results.

COMPLICATIONS

Flap Necrosis

Partial or total flap necrosis can be avoided by carefully evaluating potential risk factors prior to reconstruction. When compromised tissue vascularity is suspected, such as in the setting of smoking, diabetes, vascular disease, or prior irradiation, augmentation of flap vascularity may be considered by performing deep-plane dissection during flap elevation. Excessive tension is a frequent factor contributing to distal flap necrosis in cervicofacial advancement flaps and should be assiduously avoided during flap inset.

Ectropion

Ectropion, or eversion of the lower lid away from the globe, can result from cheek reconstruction due to proximity of the lower lid and is one of the most difficult complications to treat.

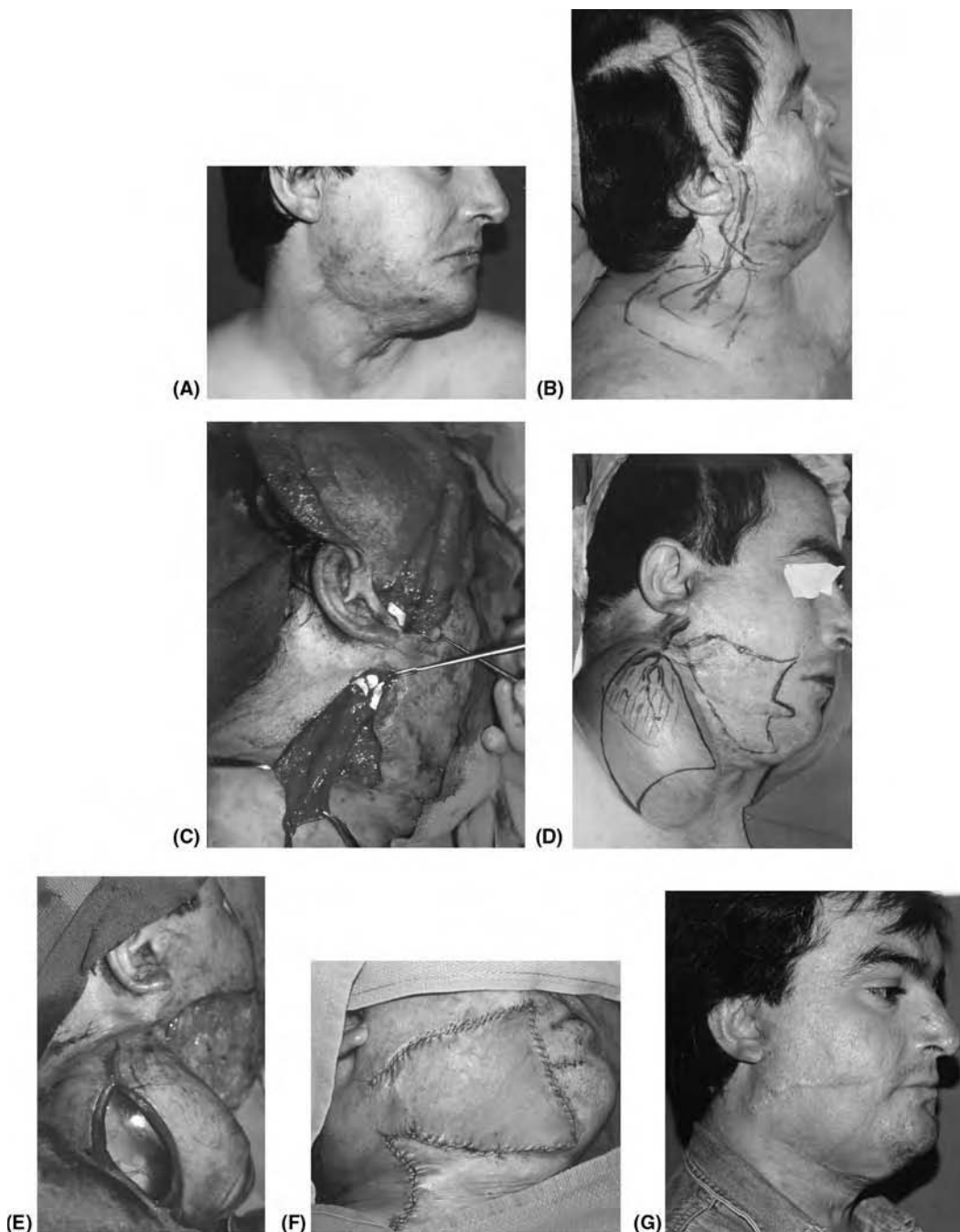


FIGURE 7 Flap prefabrication. (A) A 25-year-old man with a painful, hypertrophic burn scar on the right cheek and jaw. (B) Design of flap prefabrication using superficial temporal vessels and TPF, which will be rotated into normal upper neck area. (C) Intraoperative view of pedicle and TPF, surrounded by Gore-Tex® cuff around its base, being placed into the lower neck; it will be placed directly underneath the skin and over a tissue expander, which is minimally inflated initially. (D) Eight weeks later, at the time of scar excision and flap transfer, the expanded, prefabricated flap has an excellent Doppler signal. (E) Intraoperative view of the raised prefabricated flap, the underlying tissue expander, and the recipient bed, where the burn scar has just been excised. (F) After the prefabricated flap is inset and donor site is closed. (G) Three months after the prefabricated flap transfer. *Abbreviation:* TPF, temporoparietal fascia.

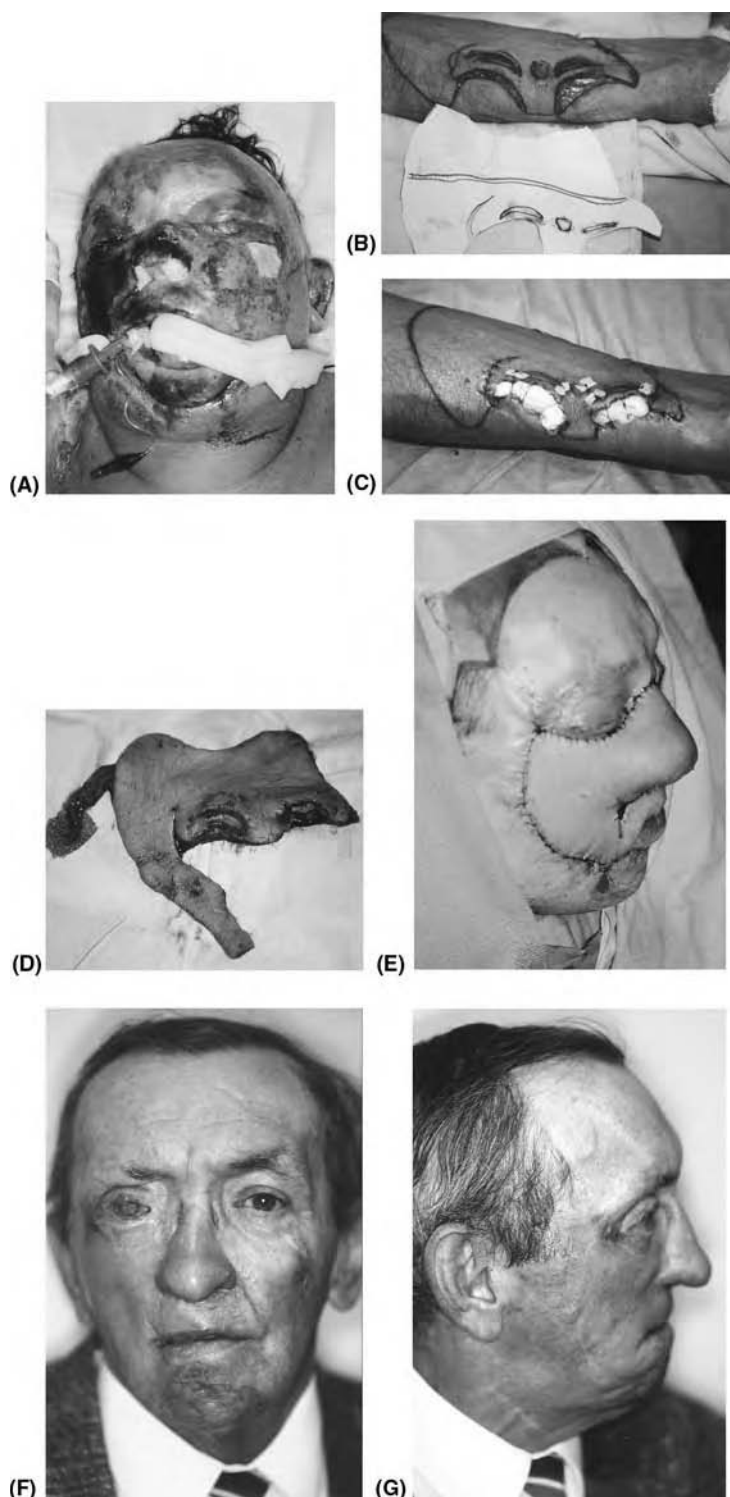


FIGURE 8 Flap prelamination. (A) A 62-year-old man with an extensive full-thickness thermal injury of nose, right cheek, and upper lip. (B) Design of prelaminated flap on right forearm, showing pattern and cartilage grafts to be inserted into flap. (C) Intraoperative appearance after placement of cartilage and skin grafts for nostril lining. (D) Harvested prelaminated flap for nasal, cheek, and upper labial reconstruction. (E) Immediate postoperative result after flap inset and revascularization. (F, G) Result at six months.

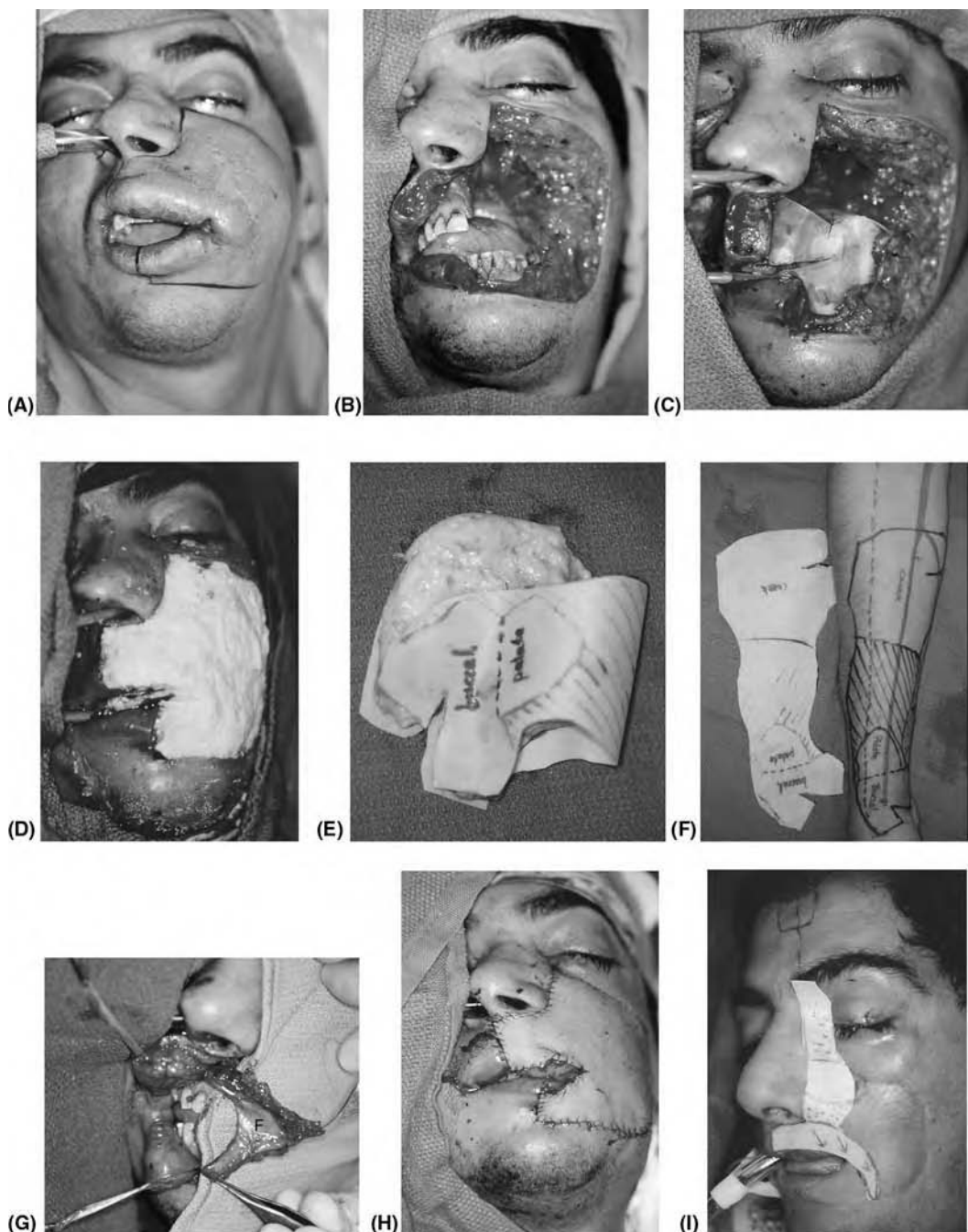


FIGURE 9 Combination of several reconstructive methods. (A) A 38-year-old man with an AVM of left cheek, left maxilla, and upper/lower lips. (B) View after radical excision of an AVM, including cheek, left hemimaxilla, half left upper lip, and oral commissure. (C) Intraoperative “scaffolding” using rigid plastic material, prior to pouring alginate mold. (D) Intraoperative alginate mold. (E) An Esmarch bandage was wrapped around the mold to convert the three-dimensional model into a two-dimensional pattern. (F) Transfer of the two-dimensional pattern to the forearm in preparation for a radial forearm free flap. (G) Contralateral facial artery musculocutaneous flap was pedicled across to reconstruct the upper lip and palmaris longus was used as an oral sling for the commissure. (H) Photograph demonstrating inset of cheek and upper/lower lip cutaneous skin paddle. (I,J) He subsequently underwent bony reconstruction of the left maxilla using free fibula complicated by a wound dehiscence on the left cheek resulting in a medial cheek defect. Extended forehead flap with hair-bearing scalp was used to cover the cheek defect and to create a moustache.

(Continued)

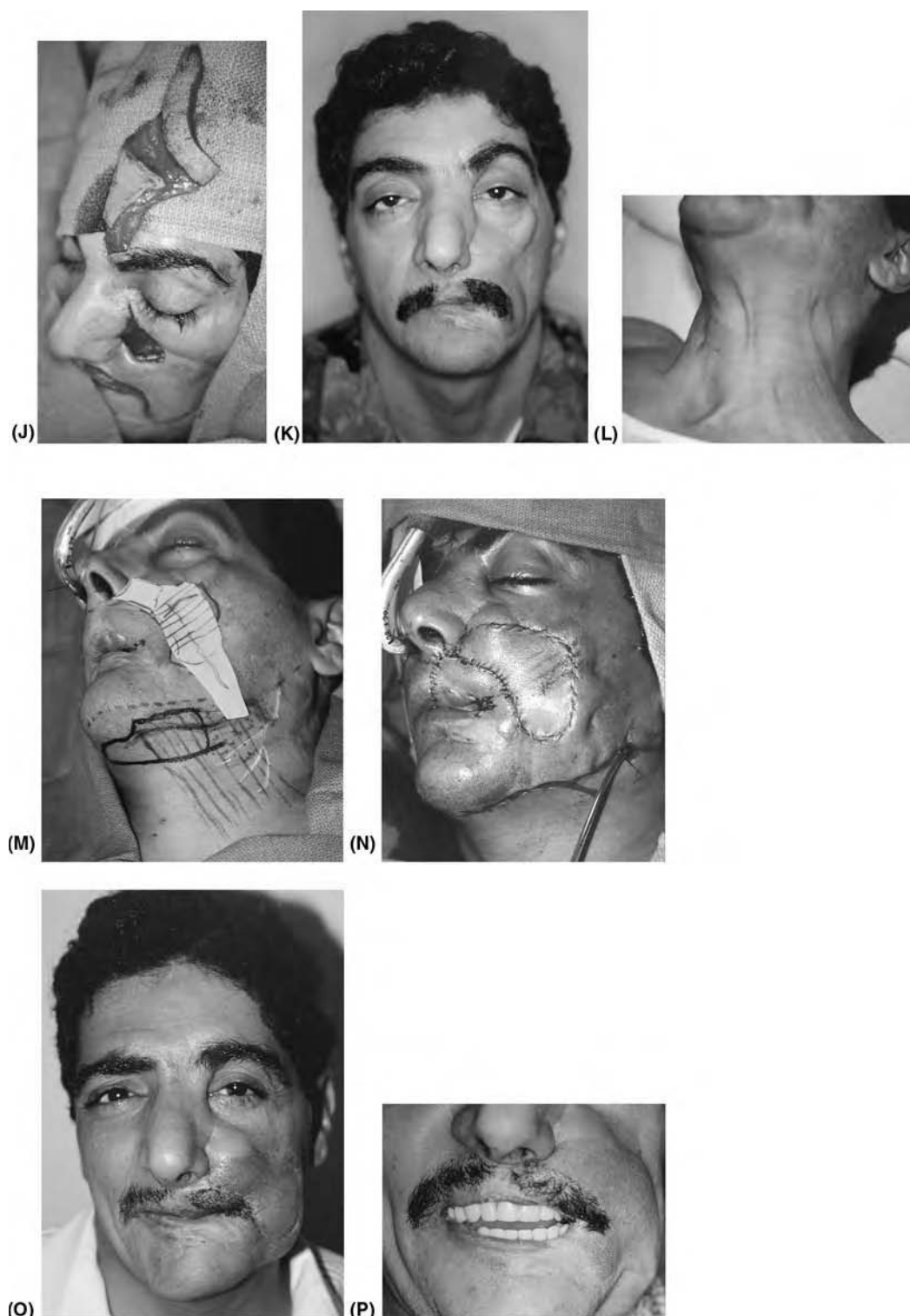


FIGURE 9 (Continued) (K) Photograph six combination months postoperatively following revision of upper lip with full-thickness hair-bearing scalp graft and release of tight oral commissure. (L) Functional submental flap planned to provide functional restoration of L cheek. (M) Functional submental flap based on submental vessels and cervical branches of the facial nerve. (N) Functional submental flap inset. (O) One-week postoperative result showing restored function. (P) Two-year postoperative result. *Abbreviation:* AVM, arteriovenous malformation.

This cosmetic and functional deformity can be caused by gravitational and/or contraction forces that result from poor preoperative surgical planning and flap design. Chronic ectropion can lead to corneal exposure and injury, keratinization of the conjunctiva, chronic ocular irritation, and visual loss. In order to minimize the risk of lower lid malpositioning and ectropion during cheek and lower eyelid reconstruction, it is important to achieve wide undermining of the flap followed by tension-free flap inset in an overcorrected position. Additional support can be attained by the use of anchoring sutures to the periosteum, performing lateral canthalplasty, canthopexy, and horizontal eyelid shortening (47).

Disruption of Hairline

Poor preoperative planning can lead to disruption of the hairline after flap reconstruction. For instance, incision for a medially based cervicofacial advancement flap should be designed in such a way as to avoid anterior displacement of the sideburn or the beard in male patients.

CONCLUSION

Reconstruction of complex cheek defects can be one of the most technically challenging but professionally rewarding tasks for a reconstructive plastic surgeon. Achieving optimal results requires thorough familiarity with intricate regional anatomy, sound clinical judgment, and technical skill. The wide variety of reconstructive options can be bewildering for the less experienced but provides outstanding opportunity for pleasing aesthetic and functional restoration.

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17 Facial Fractures

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INTRODUCTION

The treatment of facial fractures can be one of the most gratifying endeavors a surgeon may undertake. We identify an individual more by their facial appearance than any other anatomical features. What could be more rewarding than to take a mutilated face, put together the pieces of the puzzle, and restore that individual's most important identifying features and return them back to society and their families?

PHYSICAL EXAMINATION AND SOFT-TISSUE CONSIDERATIONS

The first principle to remember when possibly distracted by the looks of a horrific maxillofacial injury is the ABC's, which is not supposed to mean Airway, Breathing, Call the maxillofacial surgeon. These principles become instinctive for most of us who spend a lot of time in the Emergency Room. When faced with the horror of a self-inflicted gunshot wound to the face, with most of the facial features missing, it is easy for even the hardened nurse or surgeon to get distracted and feel uncomfortable. Airway is key, and the issue to remember in maintaining it includes consideration of the condition of the cervical spine (C-spine). I try to train my residents to assume that many of the "basics" of trauma stabilization may have been overlooked.

It is possible, but rare to require an emergency tracheotomy. A frequent problem following a gunshot wound is that the symphysis of the mandible is destroyed, which results the loss of mandibular support and the tongue falling posterior to occlude the airway. An anterior jaw thrust of the angle of the jaw is not going to help the patient with a missing or flail anterior portion of his mandible. Even the patient with the worst gunshot wound to the face will often be able to maintain their airway if they are positioned in a way that they can clear their secretions, and prevent their tongue from falling posterior. If they are upright or their face is turned to the side, while their tongue is in a dependent position, they may be able to clear their secretions.

The key is consideration for the C-spine, and whether it needs to be cleared. The incidence of C-spine fracture associated with maxillofacial fractures varies between 0.6% and 2%. Patients are often distracted by their facial pain or other injuries to give a reliable history for a C-spine injury, and are often under the influence of drugs or alcohol. Even patients, who are sober and deny any neck pain initially, often complain of neck pain on the next day when they are on the operating table due to musculoskeletal pain or spasm (1–4).

The neck examination should include posterior palpation for a C-spine injury, and anterior palpation to rule out a possible laryngeal fracture.

The basic examination should occur systematically including the neurologic examination, the examination of the scalp, eye, ear, nose and throat (mouth), and palpation of the facial bones.

Neurologic

In addition to assessing the patient's neurologic status and Glasgow Coma Scale (scores can range from a low of 3 to a high of 15), it is important to assess the patient's cranial nerves. Of key importance is a careful examination of cranial nerve VII in patients who have sustained facial lacerations, and also to confirm sensation (or numbness) in the V1, V2, and V3 portions of the face. V1 may be out with a superior orbital rim and /or frontal sinus fracture. V2 may be out

with an orbital blowout, or an orbital floor fracture. Sensation in the V3 distribution is commonly affected following a mandible fracture (5,6). Repair of the facial sensory branches has been documented in the literature, but is usually not performed. Patients may have some sensory recovery even when these branches have been avulsed. Decompression of a compressed nerve by proper fracture alignment may have a significant contribution to enhance the likelihood of sensory recovery. I have occasionally debrided bone that I felt has been impacted around the infraorbital foramen and have felt that this maneuver has attributed to the return of function of this nerve.

Injury to the main trunk of the facial nerve must be considered in patients who have sustained significant temporal bone fractures. The prognosis for recovery is inversely proportional to amount of time that it takes to perform a boney decompression of the nerve.

Injuries to the main trunk of the facial nerve are uncommon once the nerve leaves the boney canal because of its depth in the soft tissue and parotid gland. Lacerations to the distal branches are much more common, and can easily be missed, if the physical examination is being performed with the patient's facial muscles at rest. Once the laceration has been injected with local anesthesia one must wait until this has completely worn off to repeat the neurologic examination.

Of the five branches of the facial nerve, the injuries with the worst long-term results if unrecognized or unrepaired are lacerations of the frontal (temporal) branch, and the marginal mandibular branch (7). In addition to the lack of facial animation from a laceration to the frontal branch, there are long-term concerns of significant brow ptosis (8).

Pitanguay described the course of the frontal branch of the facial nerve as running from a point 0.5 cm below the tragus to a point 1.5 cm cephalad to the lateral eyebrow (9). Generally, if the laceration is lateral to the lateral border of the eyebrow it can be repaired. Older texts have suggested that the frontal branch is a single branch. I have generally been able to find and repair three to four branches. Texts suggest that you can wait up to 72 hours and still find the distal branches of the frontal branch of the nerve to perform a repair. The branches are so small that I find the nerve stimulator very useful in finding the distal branches of the nerve. I recommend performing an immediate repair. My experience is that the nerve stimulator is not as effective in finding the distal branches if the repair is delayed by 24 to 48 hours, furthermore, with a delay the "white" nerves have hemosiderin staining and are much more difficult to visualize.

Scalp

An incredible amount of blood loss can result from a delay in the repair of a scalp laceration. Shaving the hair is convenient for the surgeon, but is not necessary from the standpoint of sterility, even if an intracranial approach is necessary.

Skin

Proper cleaning, irrigation, and debridement is key. It is especially important to make sure that any material that may cause tattooing is removed. A significant percentage of serious tattooing of the face in our institution is related to the failure of being aggressive enough with the initial scrubbing of the lesions, which may often require local or general anesthesia. Delayed diffuse tattooing may be difficult to address, even with techniques of excision and dermabrasion.

Eye

A complete eye exam should be performed, including an examination of the pupils, their reaction to light and accommodation, examination of the extraocular muscles, and if possible a complete fundoscopic examination. The most important and immediate part of the eye examination is to confirm that the patient can see with both eyes, and determine the patient's visual acuity. Other details to examination include making sure that there has not been a globe rupture, foreign body, hyphema, or corneal abrasion. It is important to determine if the patient has contacts on and if possible to remove them if the patient is unconscious or likely to go to the operating room.

Major soft-tissue concerns include lacerations through the brow, eyelid, and of the canalicular system. A recommendation during the brow repair is not to shave the brow.

Through and through lacerations of the eyelid require a repair of the tarsal plate and skin. Care should be taken to make sure that none of the sutures will cause corneal irritation.

Canalicular repair includes the need for long-term stenting with a silastic tube.

Ear

The surgeon should be certain that the tympanic membrane is intact and that there is no blood or cerebral spinal fluid draining from the external canal, or evidence of a hemotympanum. A cauliflower ear needs to be drained, with an external stent placed, or a drain inserted. Without stenting or drain placement, the majority will recur.

Infection of the cartilage following a through and through laceration of the auricle is a rare but serious problem. In a contaminated wound I recommend an aggressive debridement of the exposed cartilage and a simple anterior and posterior skin repair.

Nose

Nasal fractures are the most common facial fractures. It is important to make sure that the patient does not have a septal hematoma that has to be drained. If there has been a significant mucosal tear consider silastic stenting to avoid a later constriction and airway compromise. A meticulous layered repair and proper apposition of the cartilage is important.

Throat

Examination for a sublingual hematoma is suggestive of a mandible fracture. It is important to assess the patient's occlusion, and check for instability of the patient's midface. Unstable or avulsed teeth are important to note. If the avulsed teeth are present they may be viable if they are quickly replaced (assuming that the patient is conscious and cooperative and will not aspirate them). Removal of the patient's dentures is important as part of the examination process, and in getting the patient ready for the operating room. If a patient has a palatal laceration, one should be suspicious that there may be a significant palatal fracture with palatal displacement.

Repair of intraoral lacerations can significantly decrease the patients' morbidity and postoperative pain.

Neck

Check the neck, and recheck it with palpation anteriorly and posteriorly! In addition to concerns for a cervical fracture, laryngeal fractures can lead to significant airway problems and difficulty with intubation. A bad laryngeal fracture is a contraindication for a cricothyroidotomy and may be an absolute indication for an emergency tracheotomy, if the airway is significantly compromised.

A critical decision is whether the patient needs to have a neck exploration, especially if the platysma has been violated.

RADIOLOGIC WORKUP OF MANDIBLE FRACTURES

Radiologic evaluation of the C-spine may be the most important part of the radiologic workup in the evaluation of facial trauma. Cross table C-spine films have been largely replaced by computed tomography (CT) imaging, often combined with controlled flexion extension views under fluoro and/or MRI in cases where there may be concern for ligamentous cervical injury.

Periapical View

The periapical view provides a high resolution image of a limited area. It can be of particular value if there is question of a dental root fracture or clarifying whether there is a subtle minimally displaced fracture. It can also be of great value if there is suspicion of tooth pathology or a periapical abscess (10). Although the periapical view would be available in all dental offices, it is not available to some of us in a hospital setting.

Plain Films

Standard plain views include posteroanterior, oblique, Towne's, and possibly a lateral view. Few maxillofacial surgeons rely on these views unless more sophisticated radiologic modalities are not available. One possible exception is the Towne's view, which can be a great assist particularly in the evaluation of subcondylar fractures and determining whether the fracture is medially or laterally displaced.

Panoramic Radiography

Panoramic radiography is also referred to as the panographic view, pantomography, orthopantomography, and often by the brand name Panorex. This view offers a view of the entire mandible and maxilla with visualization of all of the teeth. It can also offer special focused views of the temporal mandibular joint (11). The basic principle of the pantomogram allows movement of X-ray film and the X-ray source about a shifting center of rotation (the mandible or even a special view of the midface). As traditional panoramic views are taken with the patient sitting in an upright position, this is problematic in circumstances involving an unstable polytrauma patient with C-spine X-rays that have not been cleared.

Some institutions have been fortunate to have special modified pantomogram machine that have allowed for a high-quality pantomogram to be obtained while the patient is in the supine position. To the best of my knowledge, these machines are no longer being manufactured, and many of fear that in the near future replacement parts for these devices will no longer be available.

Controversy exists over which radiologic views are preferable in the assessment of mandibular fractures (12–15). Most surgeons consider a panoramic view as being superior to plain views (16). The standard of care in the past has been to obtain a panoramic view with a posterior-anterior (PA) view or reverse Towne's view.

Occlusal View

An occlusal view may be obtained by placing X-ray film in a patient's mouth in a horizontal position between the maxillary and mandibular teeth (in an occlusal position). The X-ray tube is then placed in the submental position. The X-ray produced is an excellent view of the anterior portion of the mandible and can demonstrate symphyseal and parasymphyseal fractures (17). This also provides an excellent tool intraoperatively to help demonstrate the adequacy of the reduction and to rule out possible lingual splaying of the mandible. This can be particularly problematic in a comminuted fracture, or a symphyseal fracture with a concomitant subcondylar fracture, or in a patient with poor dentition and difficulty in finding an adequate number of wear facets to determine the premorbid occlusion.

Computed Tomography

CT is quickly replacing other modalities of radiologic workup for mandibular trauma (18–19). Publications of studies from the early 1990s did not find the CT to be superior to other more inexpensive radiologic views. Since then, the resolution of the CT has increased phenomenally. Many of us are finding that the plain CT and 3D CT are revealing fractures that are often not visualized on the pantomogram. Furthermore, the 3D CT often provides the surgeon with a much better understanding of the complexity of comminuted fractures.

The other major issue for the maxillofacial surgeon is the fact that nearly all trauma hospitals in North America have the availability of high resolution CT with reformatting capabilities. Many of these institutions do not offer pantomograms.

A major disadvantage that maxillofacial surgeons have had over other forms of orthopedic surgery has been the general inability (except for the occlusal view) to perform an intraoperative radiologic evaluation of the fracture reduction. Although some centers report to availability of intraoperative CT, this has not been the standard of care, and is unlikely to be available for most of us in the near future.

RADIOLOGIC WORKUP OF MIDFACE FRACTURES

Plain films of the midface offer little help for the maxillofacial trauma surgeon except to highlight the location of plate and screw placement following maxillofacial surgery. In some states where an assault causing a fracture is considered a felony, a nasal view may be beneficial for medical legal documentation. Plain films may at times demonstrate that a patient has sustained a fracture, but the key question facing the surgeon regarding midface fractures is not whether a fracture has occurred, but whether the fractured segments are displaced, and the degree of displacement. These details are very difficult (or impossible) to determine from plain films.

Fine axial cut CTs using spiral technology has become the standard of care (20,21). With the evolution of high quality of reformatting of images, the coronal view is also very useful. The oblique parasagittal view through the orbit along the path of the optic nerve is also an excellent view to obtain a global assessment of orbital floor and orbital roof displacement.

Basically, the best CT views for facial fracture displacement are the views that are perpendicular to the structure being assessed. Therefore, the best view to examine the orbital wall is generally the axial and coronal views. The axial view is a very poor view for assessment of an orbital floor fracture with the coronal and oblique parasagittal views offering an excellent view. A notable exception to this rule may include palatal fractures where the displacement is often well visualized on the axial view.

TREATMENT OF MANDIBLE FRACTURES

Principles of Mandibular Fixation

Key goals in addressing mandible fractures include the need to restore the patient to their pre-morbid occlusion, preserve (when possible) previous functions of mastication, dentition, range of motion, sensation, and facial nerve function. The other goal is to try to achieve all of these goals leaving as minimal of a scar as possible. It is important to have an understanding of the variability of the anatomy of the mandible through its various parts, as well as the forces on those parts, and the concepts of "load bearing" and "load sharing." (22)

The use of maxillomandibular fixation (MMF) with arch bars to assure restoration of proper occlusion has been the hallmark of mandibular fixation. Through the years, the methods of achieving MMF have become more varied and controversial. Methods have included methods as diverse as various forms of loops (Ivy and Ernst ligatures), the use of larger intradental wires that have been lodged between the maxillary and mandibular teeth, screw placement in the maxilla and mandible with wires or elastics placed between the screws, and manual reduction with MMF while plates and screws are placed. Controversies continue to rage regarding the adequacy of many of the newer and faster modalities. The controversies have been based on such questions as to whether these modalities offer adequate stability. Screw placement has been associated with dental root injury.

The development of techniques of open reduction and internal fixation (ORIF) for the long bones gave maxillofacial surgeons new tools for ORIF to the mandible and the midface. It allowed techniques of more rigid fixation with earlier opportunities to return to function and specifically the functions of mastication. In the 1970s and 1980s, there appeared to be two divergent philosophies for the management of routine mandible fractures. One group championed by Maxime Champy favored the use of smaller plates and screws for to achieve adequate stability of the mandibular fractures (23–32). The second philosophical approach championed by AO/ASIF (Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation) and Luhr emphasized rigid fixation with larger plates and screws, with the common use of compression plating (33).

Ellis examined various treatment modalities for mandibular angle fractures. He demonstrated a high complication rate using the old standard AO fixation techniques in comparison with the Champy technique using a small plate on the superior border of the mandible (34).

In a prospective study by Ehrenfeld et al., patients were equally distributed among three different treatment groups. The lowest complication rate occurred in the group with MMF and

wire fixation, followed by the group with mini-plates, with the third group with large 2.7 mm plates having the highest complication rate. As a result of the Ellis and Ehrenfeld studies, there has been a trend away from the use of larger compression plates for routine, noncomminuted, noncomplicated mandibular fractures (35). The use of large bicortical screws and compression plates for mandible fractures is not longer taught as "AO technique."

Larger more rigid traditional reconstruction plates are being replaced by various forms of locking screw plates. Using this technique the screw head locks into the plate (often with independent treads on the screw head), while the tread on the shaft of the screw has a separate set of treads that lock in to the bone. This represents a fairly revolutionary concept compared to previous techniques where the screws would lag tighten the bone against a rigid plate. Using the old technique, if the contour of the reconstruction plate was not perfect, the mandibular fractures were often distracted as the screw was tightened, resulting in a possible malunion and malocclusion. Using the newer locking screw techniques, the plate serves as a form of internal "external fixator." This allows for greater three-dimensional stability that is achieved with the screws allowing adequate fixation even in cases where the reconstruction plate is not in contact with the bone. As a result, small contour imperfections while bending the plate does not necessarily mean that there will be problems of malalignment and subsequent malunion.

Numerous forms of fixation are acceptable to achieve adequate fixation. For routine, uncomplicated mandibular fracture two mini-plates will offer good fixation for most fractures. Previous traditional AO teaching used to emphasize the placement of a superior smaller tension band plate with monocortical screws on the cephalad portion of the fracture with a larger inferior plate using compression plating with bicortical screws. A larger locking plate may be adequate (but may be stronger and larger than is necessary). Symphyseal fractures may be treated with two lag screws. Three-dimensional box plates are becoming more popular for all mandibular fractures, and can be particularly effective in resisting the torsional forces that are maximal in the symphyseal area.

Parasymphyseal fractures are as amenable to all of the modalities of fixation as symphyseal fractures, with the exception of the use of two lag screws, as there is generally not enough room caudad to the mental foramen at this portion of the mandible for placement of two screws. Box plates, (three dimensional plates) are difficult to use in the parasymphyseal area because of the proximity of the mental foramen.

Body fractures are amenable to all of the modalities of fixation as the parasymphyseal area, and box plates are also easy to use in this area.

Angle fracture management has resulted in a higher complication rate than the other portions of the mandible, possibly because access is more challenging. All of the modalities that are used in the body can be used in angle fractures. Placement of plates on the inferior angle of the mandible can present a challenge, even with the use of a trochar because of poor visibility, unless using an extraoral incision. This extraoral incision is associated with a scar and risk of injury to the marginal mandibular nerve. Champy's major contribution was the realization that for a simple angle fracture, the placement of a single mini-plate at the superior rim of the fracture generally will provide adequate fixation, due to load sharing of the remaining bone, caudad to the position of the plate. The placement of a plate in this position is relatively easy compared to plates placed at the inferior mandibular border.

Vertical ramus fractures are generally quite stable because of the unique surrounding periosteal-muscular sling. They are often nondisplaced, in which case they can be treated with a soft diet and no fixation.

Coronoid fractures need not be treated.

Condylar head fractures (intracapsular fractures) should again be treated with a soft diet and mobilization of the mandible to avoid ankylosis.

The treatment of subcondylar fractures represents an area of most glaring controversy. There is little agreement either on the indications for treatment of subcondylar fractures or on the method of treatment. Open reduction of these fractures is difficult because of the dangers with access due to the facial nerve, as well as the small amount of bone in the neck of the mandible, and confounded by the poor visualization offered by many approaches. The "standard of care" for years has been MMF. Many authors have suggested that it is better to get these patients

moving freely or at least with training elastics. Within recent years many surgeons have advocated more aggressive approaches for ORIF including, preauricular, Risdon, retromandibular (transparotid), and even various endoscopic approaches (36–39). Many of these approaches are fraught with difficulty, especially to the inexperienced surgeon.

Relative indications for ORIF of subcondylar fractures include panfacial trauma with bilateral subcondylar fractures, where the height of the face will be determined in part by re-establishing the height of the mandible by repairing the subcondylar fracture (at least on one side). Indications for ORIF based on angulation of the fracture or dislocation of the condyle are based largely on opinion rather than randomized prospective studies.

Despite the tendency to use smaller plates and screws for simple, noncomminuted fractures, patients with “defect” type fractures and deformities will benefit by the use of larger reconstruction or locking screw plates. These “defect” types of fractures include fractures that are unstable and lack the ability to have sufficient bone for load sharing. This includes mandibles with missing bone from gunshot or tumor extirpation, comminuted fractures, edentulous mandibles with significant bone atrophy, and infected fractures with failed fixation that need to have a larger plate span the infected area, free of screw fixation in that area (40).

Complications include malunion, malocclusion, infection, and nonunion. Infection should be regarded as a problem that likely needs surgical intervention, and is often caused by a failure of fixation with loose hardware or a loose sequestrum of bone, or abscessed tooth that may need to be extracted (41–55).

ORBITAL ZYGOMATIC FRACTURES: ORBITAL AND ZYGOMATICO-MAXILLARY-COMPLEX FRACTURES

Orbit and ZMC: A Combined Problem and Topic

Orbit and ZMC fractures are presented together because, with the exception of a pure zygomatic arch fracture, it is difficult to have a zygoma fracture without also having an orbital fracture (56). Proper reduction of the zygoma is often “key” in also properly reducing the orbital fracture. The zygoma includes the territory defining part of the orbital floor and lateral orbital wall, commonly involved in orbital fractures. As part of the reduction of a complex orbital and ZMC fracture it may be essential for the surgeon to expose the lateral orbital wall and properly align the greater wing of the sphenoid and the zygoma, which together define the lateral orbital wall (57). Other fractures that do not involve the zygoma but may be significant include the medial orbital wall and the orbital roof.

Initial Physical Examination and Management

From a maxillofacial trauma standpoint, the highest priority regarding the history and physical, after addressing the ABC’s, neurologic status and C-spine, is confirming that the patient has vision in both eyes. Most midface and orbital surgery is somewhat “elective,” but if the patient has no vision or has vision which is deteriorating, most consider it a relative emergency to get ophthalmology involved, perform an aggressive workup including an emergency CT with fine cuts through the orbit, and determine the cause and whether it may be reversible (58).

Controversy continues regarding the issue of whether decompression of a bony spicule pressing on the optic nerve, especially in the optic foramen will be beneficial. The decision to intervene surgically versus the use of high dose steroids may be largely dependent on the experience and comfort level of the various specialists in your institution. The issue of the relative “emergent” need to decompress an entrapped extraocular muscle is similarly controversial. The majority of patients presenting with double vision do not have entrapment. Diplopia is commonly due to injury or edema of the extraocular muscles or possibly due to trauma to the nerves to these muscles. One must have a higher index of suspicion for entrapment in pediatric fractures. A “forced duction test” may be needed to confirm entrapment. Many believe that if the patient has true entrapment, they should be explored (if possible) on the day of the trauma. It is essential to have the patient comfortable in order to perform valid forced duction. When in doubt, it may be important enough to consider the use of anesthesia to accomplish this test.

The physical examination is important, and at times our best eye examination can be obtained immediately after the patient first arrives in the emergency room, before the periorbital edema becomes severe. Keeping the head of the bed maximally elevated and preventing the patient from blowing their nose are two points our general surgery colleagues often overlook. Pneumo-orbita from blowing ones nose can significantly exacerbate periorbital edema, and complicate the assessment and treatment of periorbital trauma. Do not overlook a corneal abrasion, hyphema (blood in the anterior chamber), globe disruption, and retinal detachment. A retinal detachment can be very difficult to diagnose with a routine fundoscopic examination, without dilation of the pupils and a bright light examination. Therefore, an ophthalmologic consult is recommended preoperatively in patients who have sustained periorbital trauma.

Another key part of the examination, especially when assessing the patient for enophthalmos is to perform the “worms eye” and “birds eye” view of globe projection relative to the mallar eminence, and relative to the frontal bar. Common findings with enophthalmos include a superior sunken sulcus of the upper eyelid, and an increased distance between the upper lid lashes and the eyebrow on the affected side. The relative position of the mallar eminence can sometimes be assessed from side to side by comparing the distance of the eminence to the frames of a patient’s eyeglasses.

Radiographic Assessment

The majority of patients with a blow-out fracture present with proptosis due to edema, and not with enophthalmos. Enophthalmos is often a delayed finding after the edema has improved. As a result, fine cuts with the CT, with reformatted views are essential. Fine axial cuts with reformatted coronal and oblique parasagittal views are very useful. The oblique parasagittal view through the optic nerve is singularly the most useful cut in giving the best overview of the orbital floor and the orbital roof (59,25). On the axial cuts, pay close attention to the medial and lateral orbital walls, and in particular the step off between the greater wing of the sphenoid and the zygoma.

Surgical Approach to the Orbit

The ideal orbital approach remains controversial. Ellis and Zide have outlined most of the current approaches. Trends have been to abandon the eye brow incision as an approach to the zygomatico-frontal suture because it leaves an unsightly scar, and now prefer the upper eyelid “bleph” incision. Approaches to the orbital floor include the subciliary incision and the conjunctival incisions. High subciliary incisions are linked to a higher incidence of ectropion, and making a mid eyelid incision is safer. Conjunctival incisions include incisions anterior or posterior to the inferior orbital septum. If done properly, these incisions minimize the risk of ectropion, but there may be a small risk of entropion with the conjunctival approach. The medial wall can be approached through a caruncular or retrocaruncular incision that is generally connected in continuity with the conjunctival incision (retroseptal). The orbital rim incision offers a very direct incision, but often leaves an unsightly scar.

At the time of exploration, a maximum effort should be made to correct the orbital anatomy (reconstruct the orbital walls) and restore the orbital volume, without causing an iatrogenic entrapment (60–62). Every material imaginable has been used for the reconstruction of the orbital floor in a blowout fracture. For years split calvarial bone graft was the standard of care. A favorite material over the last 12 years has been the use of titanium mesh, and more recently materials such as Medpore. In complex cases, the use of a sterile skull, or a skull placed in a sterile bowel bag is very useful, both for the overall midface reconstruction, and in contouring the material to be placed in the orbit. An important step is to perform a “forced duction test” after placing any material into the orbit in order to confirm that the soft tissue has not been entrapped.

Correction of Orbital Anatomy and Orbital Volume

A distinct advantage in the use of mesh is that it allows granulation through the interstices of the mesh with the secondary formation of new sinus or naso-pharyngeal mucosa, and incorporation of the mesh into the soft tissues (63,64). This is probably the main reason that many of us have had such a low complication rate with infection using mesh (65,66). The other advantage is that

it will show up well on a postoperative CT (unlike Medpore and some other materials). In the event that there is suspicion that the correction has not been perfect, a postoperative CT can be very useful to confirm the contour of the orbit, and the placement of the mesh.

The main challenge in orbital reconstruction, or any midface reconstruction is to attain the appropriate reduction. We refer to this as a proper ORIF. When an undesirable result is noted it is often because the fractures have been opened and internally fixated but not properly reduced (OIF). Key principles to avoid an OIF include exposing all of the fractures before beginning the reduction and plating. In complex zygoma fractures, it is very useful to explore and visualize the lateral orbital wall to confirm that the fracture between the zygoma and the greater wing of the sphenoid has been properly reduced. This singularly may be the most important landmark to examine, unless the lateral orbital wall is comminuted. Beat Hammer has even advocated placing a plate and screw at this location (30).

Chronic enophthalmos remain a challenge to all of us (67,68). The most important key to its management is to be maximally aggressive with the early treatment of orbital fractures to try to prevent it from happening in the first place. An exophthalmometer can be very useful in the hands of a surgeon in assessing enophthalmos. If it is to be useful, the Naugle exophthalmometer is more likely to be useful than the Hertel exophthalmometer. The advantage of the Naugle is that it rests on the frontal bar (which has not been displaced in the majority of cases) and the inferior orbital rim. Resting the Naugle on the frontal bar alone can give the surgeon an excellent reference point to measure the relative globe protrusion of the normal orbit relative to the fractured orbit (assuming that the frontal bar has not been injured and displaced). The problem with the Hertel is that it rests on the lateral orbital rim, which is commonly displaced following orbital trauma (69).

Another issue to determine is whether a patient has a significant amount of dystopia. Special tools that are helpful include examination of photographs and the use of a McCoy trisquare for assessment of canthal positioning and the position of the pupils. The goal is to restore the medial and lateral canthi to their relative horizontal positions (70). In some cases, there can be the appearance of a superior sunken sulcus of the upper eyelid, suggesting that a patient has enophthalmos, when the real problem is that the patient only has a significant dystopia.

Once determining the degree of enophthalmos, the challenge is deciding the best way of obtaining a correction (71). If an orbital floor plate was incorrectly placed, it should be replaced. Unfortunately, many of the severe cases of enophthalmos are multifactorial, with several of the orbital walls being in the wrong position, resulting in an increased orbital volume. In cases of chronic enophthalmos, the challenge for the surgeon is deciding whether to perform multiple osteotomies to correct the defect, or to use bone, Medpore, or some other substance to fill in the orbital defect to obtain better protrusion of the globe. Proper positioning of this material posterior to the orbital globe is important. The theoretical volume of material needed to correct enophthalmos is about 1cc of material for each 1 mm of enophthalmos (72). Unfortunately, due to contraction of the soft tissues it is often very difficult to pack the appropriate volume of material posterior to the equator of the globe to obtain an appropriate correction.

Reduction of the Zygoma

Proper reduction of a zygoma fracture with the appropriate rotation of the zygoma is key in establishing the appropriate width and AP projection of the malar prominence and the midface as a whole. It is also essential in establishing the proper placement of the orbital floor and lateral wall, having a significant impact on the overall volume of the orbit.

As with all maxillofacial trauma it is important to expose all of the fractures before beginning plating. A desirable approach to the zygomatico-frontal (Z-F) suture is through the upper eyelid incision. The upper eyebrow incision, which was popular for years, leaves a more accentuated scar with a parting and/or alopecia of the hair. The upper eyelid or blepharoplasty incision is as direct of an approach to the Z-F suture as the bleph incision.

Most complex zygoma fractures include a fracture of the inferior orbital aperture. A simple minimally displaced zygoma, with no displacement of the Z-F suture, may be reduced through and intraoral approach with an intraoral exposure up to the orbital aperture, taking

care not to injure the infraorbital nerve. If an adequate reduction can be performed through this approach the fracture may be treated with a single plate along the lateral column of the midface. This simplified approach should only be used for a simple fracture where the surgeon is very certain of the adequacy of the reduction of the zygoma.

For more complex fractures, the traditional reduction will require an upper bleph incision for exposure of the Z-F suture, a periorbital exposure of the inferior orbital aperture and possibly the inferior orbital floor, consideration of an exploration of the lateral orbital wall to make sure that the greater wing of the sphenoid is lined up with the zygoma, and properly reducing the fracture between the zygoma and maxilla that traditionally extends through the lateral column of the midface.

In a patient with an extremely displaced zygoma, one may want to consider a more direct visualization and reduction of the zygomatic arch through a coronal incision. Endoscopic techniques have also been described as a means for reduction of the zygomatic arch. Care should be taken with any direct approach of the arch as the frontal branch of the facial nerve passes directly over the arch. These approaches require a thorough understanding of the anatomy of this area, as well as an understanding of the fascial planes and relationship of the frontal branch of the facial nerve. Significant disadvantages of the coronal approach include problems with scar alopecia and possible temporal hollowing. In deciding whether to include the coronal incision the surgeon has to make the difficult judgment call as to whether the deformity and/or scar that is being "created" from the surgical intervention warrants the deformity you are trying to correct.

If a direct approach is used, it is important to study the contour of the arch on the contralateral side. The arch is often not an "arch" but may lie more in a direct AP position. This anatomy is somewhat variable, and it can be very easy to unintentionally plate the arch in a malposition.

Another possible fracture includes the "pure" arch fracture. This can commonly be reduced through a Gilles (temporal) or Keen (intraoral) approach. There is some suggestion that failure of reduction of a pure arch fracture may be due to failure of a proper intraoperative reduction, rather than a collapse or loss of the reduction after surgery (73).

Many of us consider the eyes one of the most important features of expression during our human interactions and conversations. Trying to appropriately restore the orbit and zygoma may be one of the most important (and sometimes challenging) facets of maxillofacial reconstruction.

NASAL AND NASAL ORBITAL ETHMOID FRACTURES

Nasal fractures represent the most common facial fractures and perhaps the most under treated. Challenges include difficulty in evaluation of the extent of trauma, comminution of segments, undiagnosed and often significant associated cartilaginous injury and displacement (septum), and a lack of adequate armamentarium to achieve adequate stabilization of reduced segments. A markedly displaced (dislocated) nose is a painful problem to send a patient home with, and can result in a significant deformity with a compromised airway. If neglected or the treatment is postponed until the fractures have healed, it can be a difficult challenge to adequately correct. Many fractures result in diffuse swelling and may benefit by allowing some time for the swelling to subside to determine if indeed there is a deformity to fix, but a patient with his nose displaced to the one side of his cheek will appreciate attempts at a reduction, and often will feel instantly better.

It is important to understand and differentiate the difference between a nasal and an NOE fracture. An NOE fracture does not necessarily involve the nasal bone. It does involve the segments of bone that anchor the medial canthus. Fracture of the NOE result in splaying of the medial canthi laterally with widening of the intercanthal distance and often nasal bridge flattening.

Markowitz published a useful classification system that both describes the extent of the fractures and somewhat dictates the complexity of the repair (74). A type I NOE fracture involves a fracture of the medial orbital aperture, which includes the bony insertion of the medial segment. As these segments involve relatively large bony segments these fractures can generally be reduced with mini-plates. Type II NOE fractures involve more comminuted

segments. The medial canthus remains attached to bone, but often to a very small segment of bone. In a type III NOE fracture, the medial canthus has become detached from the bone. Type III fractures are relatively rare. Generally if the surgeon is careful with the dissection a small piece of bone can be found attached to the canthus.

Type II and III fractures offer the biggest challenge to achieve an adequate repair. With both of these fractures it will often be necessary to anchor the medial canthus to a bony structure on the contralateral side of the orbit in order to achieve an adequate pull and reduction of the medial canthus. Another key principle in this repair is to make sure that this anchor is placed sufficiently posterior. Using a wire or large suture to pull the medial segments together can result in further lateral splaying of the medial canthi if the wire is placed through the bony structures at a point anterior to the medial canthal insertion.

LE FORT AND PALATAL FRACTURES

Le Fort fractures are based on a description of fractures by Rene Le Fort (1869–1951). They include a LeFort I fracture, at the level just above the palate, a Le Fort II fracture (pyramidal fracture) through the maxilla and naso-frontal area, and a Le Fort III fracture (craniofacial disassociation) through the zygomatico-frontal and naso-frontal areas. All three of these fractures extend posteriorly back through the pyriform plates. All three fractures result in midface instability, which can be noted by grabbing the maxillary teeth with one hand, stabilizing the forehead with the other hand, and “rocking” the midface back and forth. If the patient is unconscious the instability is noted, but it can sometimes be difficult to be certain at what level the Le Fort fracture is, especially when the patient’s face is quite swollen. When the patient is awake, the patient can often localize the pain during this movement, which can help in diagnosis the level of the fractures.

A palatal fracture that is sagittally split (or comminuted) can logarithmically increase the difficulty of the proper reduction of facial fractures, especially when it is associated with mandible fractures. In this case, determination of the proper occlusion with the proper width of the jaw and maxilla can be very difficult. If the patient has a simple sagittally split palate it may be easy to correct with a plate on the palate and anterior maxilla. If both the palate and the mandible are fractured, it may be beneficial to take dental impressions. These impressions may then be used to make dental models, and with the use of an articulator, better determine the patient’s pre-morbid occlusion. These models may then be used to make a palatal splint to assist in the palatal reduction and stabilization of the maxillo-mandibular unit.

FRONTAL SINUS FRACTURES

Key anatomical features to assess in the treatment of frontal sinus fractures include the anterior table of the frontal sinus, the posterior table of the frontal sinus, and the naso-frontal duct. The naso-frontal duct drains the frontal sinus and empties into the middle meatus. The paired frontal sinuses are rudimentary or absent at birth, and do not reach full size until after puberty.

Primary concerns with frontal sinus fractures include cosmetic contour deformity with an anterior table fracture, brain or dural injury and CSF leak with a posterior table injury, possible blockage of the draining duct, sinusitis, meningitis, mucocele, brain abscess. Stanley found that in 15% of skulls the orifice is a true duct, which is relatively small and easy to obstruct. In 85% of skulls, this is a relatively large ostia or infundibulum (75). In these cases it would be more difficult for the drainage system to be blocked. Clearly the patient’s risk of problems is related to the extent of the traumatic displacement of fractures, and also that patient’s unique anatomy.

The proper management of frontal sinus fractures is also controversial as there are no large randomized prospective studies comparing different approaches within the same institutions. A problem in analyzing outcome is that mucoceles may not become clinically obvious for several decades after the initial trauma.

An anterior table fracture should be repaired, with removal of any comminuted fragments of bone from the frontal sinus to avoid any possible blockage of the draining system and possible infection.

Management of a posterior table fracture is more controversial. A fracture without significant displacement and without a CSF leak may be managed conservatively. A posterior table fracture with significant displacement or a CSF leak should be addressed surgically unless the leak stops within a short period of time. Where the disagreement is problematic is in determining how much displacement is significant, and how long is a surgeon willing to wait for a CSF leak to stop. Gross displacement of the posterior table should be treated with removal of the sinus mucosa, obliteration of the duct, and a cranialization procedure.

If the naso-frontal duct is involved, some authors would advocate frontal sinus obliteration. The sinus mucosa is again removed, the duct obliterated, and the obliteration can be achieved with bone grafts, autogenous fat, or left open to allow for osteoneogenesis (76–78). Many surgeons have found that with meticulous reduction of the bony structures around the duct/infundibulum the frontal sinus can be preserved.

STAGING OF PANFACIAL FRACTURES

Staging of panfacial fractures can be a challenge to any surgeon. Some surgeons advocate starting from the calvarium as a stable entity and working in the caudal direction. Many (including the author) advocate focusing first on establishing the maxillo-mandibular unit, and then starting from the calvarium and working your way down. I prefer to struggle with trying to achieve an ideal occlusion early in the case. Establishing the maxillomandibular unit further helps me in establishing the proper height of the midface.

Key principles include establishment of adequate exposure of all of the fractures before starting to place plates and screws. When moving up to the calvarium a good place to start is at the zygomatico-frontal suture fractures, with initial placement of one screw into the plate on each side of the fracture, to allow the zygoma to continue to swing, until its proper three-dimensional positioning has been established. An early decision that has to be made is whether to perform a coronal incision to expose the zygomatic arch to establish proper AP projection and facial width. The coronal incision allows for excellent exposure of this area. Disadvantages of the coronal approach include scar alopecia, temporal hollowing, and risk of injury to the frontal branch of the facial nerve. A decision has to be based on how serious the deformities are, what the surgeons confidence is that they can obtain a proper reduction without using the coronal approach, and whether the “deformities” of the incision are likely to be more noticeable than what you hope to repair.

Most communication with humans is done with eye contact. Every effort should be made to correct the anatomy of the orbit as perfectly as possible. Proper reconstruction of the orbital aperture is essential. The lateral orbital wall is an excellent landmark to expose to assist in the alignment of the lateral wing of the sphenoid and the zygoma. The lateral wall may not be reliable if the lateral wall is comminuted, but it otherwise provides an excellent guide to assure the surgeon that the zygoma has been properly aligned.

Attention should then be addressed to the alignment and stabilization of the medial columns (naso-maxillary buttress) and lateral columns (zygomatico-maxillary buttress) of the midface. As a general principle start from whichever of these columns is the least comminuted to help further re-establish the proper midface height. Hopefully at the Le Fort I level the maxillo-mandibular unit and the medial and lateral columns align perfectly. If it does not line up perfectly at this point, try to back tack and see at what point something was not perfectly reduced. At the same time, it is better to be off by a millimeter or two at the Le Fort I level than to be off at the level of the maxillo-mandibular interface.

The last fracture that should be addressed is the orbital floor fracture. The last maneuver that should be performed is a forced duction of the globe to make sure that there has not been any entrapment.

The future challenge to all surgeons will be to find ways of obtaining intraoperative documentation that they have achieved appropriate reductions of complex facial fractures. Robert Stanley has reported the use of the intraoperative CT to confirm proper reductions (79). Our hope is that new innovations will allow similar radiological tools to become more routinely available in all centers.

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18 Rhinoplasty

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INTRODUCTION

Rhinoplasty is one of the most challenging and rewarding procedures in plastic surgery, requiring an artistic eye and technical finesse. The rhinoplasty surgeon must possess a fundamental understanding of the underlying anatomy as well as an appreciation for the dynamic interplay between bone, cartilage, and soft tissue. A sound operative plan founded on proper and thorough nasofacial analysis is paramount to obtaining a result that blends harmoniously with the rest of the face.

ANATOMY

It is critical that the rhinoplasty surgeon be familiar with the external skin and soft tissue, the underlying osseocartilaginous framework, and ligamentous support between these structures in order to obtain the desired result.

Skin

The nasal skin's thickness, mobility, and sebaceous character vary along its length, with the upper two-thirds averaging 1300 microns in thickness versus the lower one-third, which averages 2400 microns (1). Furthermore, the upper two-thirds is more mobile and less sebaceous than the inferior one-third. A straight dorsum is actually produced by this variation in dorsal skin thickness combined with an underlying convexity in the osseocartilaginous framework (Fig. 1).

Ethnic and gender differences in skin character should be taken into account during the preoperative planning phase, as thinner skin (typically found in Caucasians and females) will tend to show minor alterations of the underlying framework, whereas thicker skin (as in males and those of Mediterranean and African descent) will require more aggressive manipulation in order to achieve the desired result.

Muscle

Two nasal muscles, in particular, are important in rhinoplasty—the levator labii alaeque nasi and the depressor septi nasi. The patency of the external nasal valve is maintained by the levator labii alaeque nasi, while the depressor septi nasi can shorten the upper lip and alter tip projection, if overactive (Fig. 2).

During the preoperative nasofacial analysis, the effects of a hyperactive depressor septi can be recognized by a depressed nasal tip and shortened upper lip upon animation, especially when smiling. In this patient subpopulation, we perform a dissection and transposition of this muscle (2).

Blood Supply

Branches of the ophthalmic artery and facial artery serve as the blood supply to the nose (Fig. 3).

Paired columellar branches are present 68.2% of the time (3), which are mandatorily transected by the transcolumellar incision in the open approach. The lateral nasal and dorsal nasal arteries then serve as the remaining blood supply to the tip, and therefore assurance must be made to protect these vessels if the open approach is used. In this case, extended alar resections

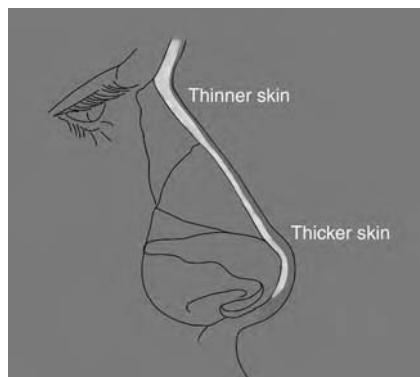


FIGURE 1 The nasal dorsal profile is a function of variable nasal skin thickness and an underlying convexity in the osseocartilaginous framework.

are avoided as the lateral nasal artery is found 2–3 mm above the alar groove and may be inadvertently injured. Furthermore, extensive debulking of the nasal tip is discouraged as this may result in injury to the subdermal plexus of the nasal tip.

The arteries travel in the musculoaponeurotic layer whereas the veins and lymphatics lie in a more superficial subcutaneous plane. In the open technique, bleeding and postoperative edema are minimized by performing the dissection in the submusculoaponeurotic plane just above the perichondrium in order to avoid injury to all of these structures (4).

Nasal Vaults

The osseocartilaginous nasal framework comprises three separate vaults: the bony vault: the upper cartilaginous vault, and the lower cartilaginous vault. The bony vault, which constitutes the upper third to half of the nose, is made up of the paired nasal bones and the ascending frontal process of the maxilla. There is variation on the thickness of the nasal bones, with the thickest portion just above the canthal level. Osteotomies are technically more difficult at this level, and are rarely performed (5) (Fig. 4).

The upper cartilaginous framework, which comprises the paired upper lateral cartilages (ULCs) and dorsal cartilaginous septum, begins at the “keystone” area where the nasal bones overlap the ULCs. This area normally is the widest part of the dorsum and resembles a “T” in cross-section (Fig. 5A and B). If this area is overresected during dorsal hump reduction an inverted-V deformity and/or disruption of the dorsal aesthetic lines may result. A graduated approach using a component dorsal septal reduction is advised to avoid these complications (6).

The lower cartilaginous framework begins where the lower lateral cartilages (LLCs) overlap the ULCs in what is called the “scroll” area. The LLCs comprise medial, middle, and

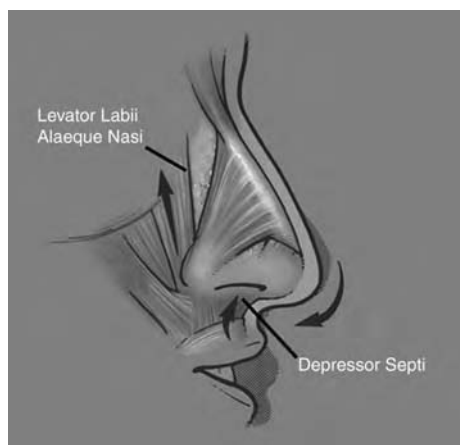


FIGURE 2 The levator labii alaeque nasi helps stent open the external nasal valve and the depressor septi can alter tip dynamics, especially if hyperactive.

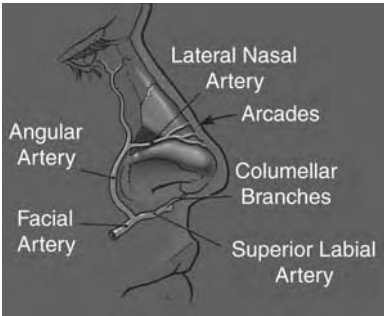


FIGURE 3 The blood supply to the nose.

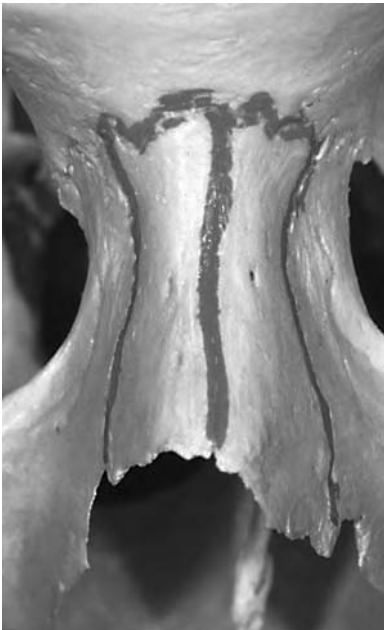


FIGURE 4 The paired nasal bones. These are thicker just above the canthal level.

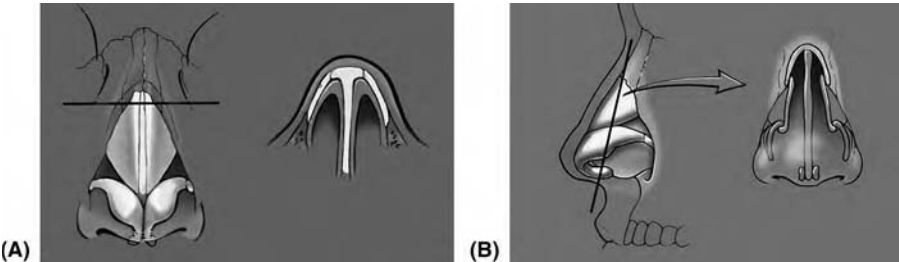


FIGURE 5 (A) Cross-sectional anatomy of the keystone area. (B) The nasal bones overlap the ULCs in the keystone area and the LLCs overlap the ULCs in the scroll area.

lateral crura and are connected to each other, the ULCs, and the septum by fibrous tissue and ligaments (Fig. 6). Tip projection can be affected by disruption of these ligaments; therefore, reconstruction of this support may be indicated in certain situations (7).

Nasal Function

The functions of the nose include respiration, humidification, filtration, temperature regulation, and protection, which are regulated by the septum, turbinates, and the internal and external nasal valves.

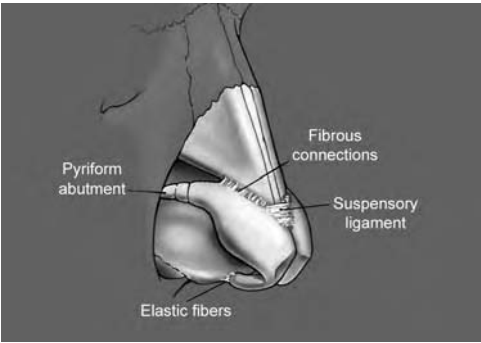


FIGURE 6 Support for the lower lateral cartilages.

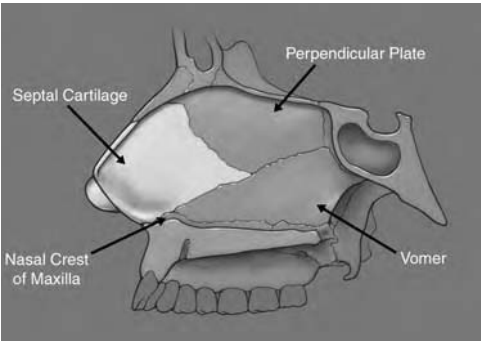


FIGURE 7 Components of the nasal septum.

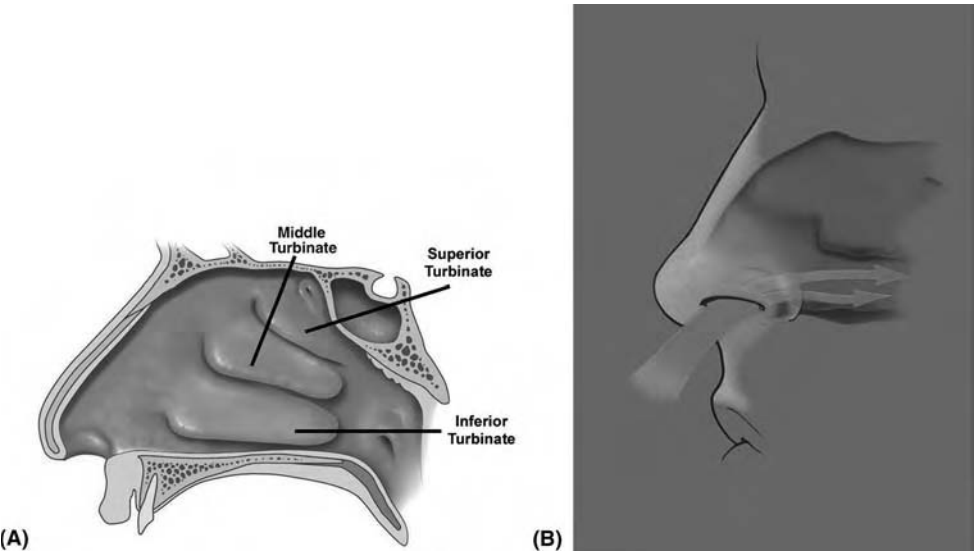


FIGURE 8 (A) Parasagittal view of the lateral nasal wall; (B) the inferior turbinate has the most significant impact as airway resistance.

The septum consists of the septal cartilage, the perpendicular plate of the ethmoid, the nasal crest of the maxilla, and the vomer (Fig. 7). Septal deformities can affect laminar airflow and can lead to secondary turbinate hypertrophy. When addressing septal deformities, it is critical to analyze and attend to all portions of the septum. Extreme care must be taken when performing a resection of the perpendicular plate of the ethmoid as it is contiguous with the cribriform plate. Disruption of this may result in devastating consequences, such as anosmia, CSF rhinorrhea, or ascending infection/meningitis.

There are three turbinates, which are mucosa-lined extensions of the lateral nasal cavity that undergo autonomically controlled cyclical expansion and contraction. (Fig. 8A). They serve to

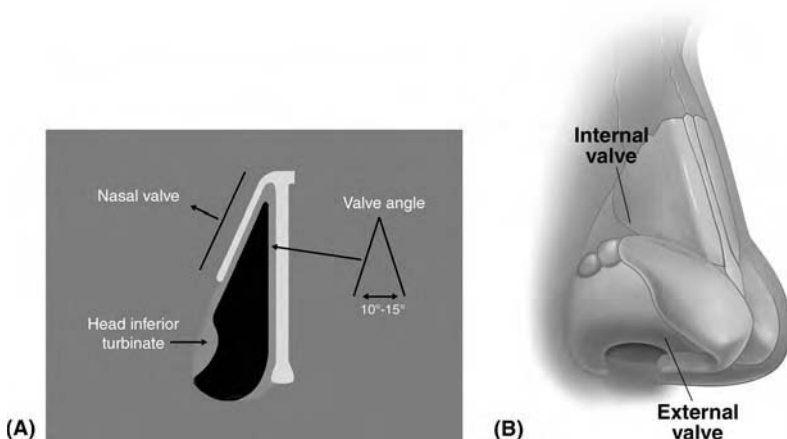


FIGURE 9 The internal nasal valve angle is usually 10–15°.

assist in air transport during respiration and condition/humidify inspired and expired air. The anteriormost portion of the inferior turbinate has the greatest impact on airway resistance, providing up to two-thirds of the total airway resistance (8,9) (Fig. 8B). Turbinate hypertrophy can be addressed in many ways; however submucosal resection and outfracture techniques remain the most common. Overresection must be avoided as it can adversely affect regulatory and physiologic functions and can lead to crust formation, bleeding, and nasal cilia dysfunction.

The nasal septum and the caudal margin of the ULC form the internal nasal valve. The angle formed by the junction of these two structures is usually 10–15° (10) (Fig. 9A and B), and can be responsible for up to 50% of the total airway resistance as it is the narrowest segment of the nasal airway. Hypertrophy of the inferior turbinate may cause further decrease of the cross-sectional area of this region. Classically, collapse of the internal nasal valve can be alleviated by lateral traction on the cheek. This maneuver, also called a positive Cottle's sign, stents open the valve and leads to increased airflow. In this case, spreader grafts may be necessary to increase the valve angle and stent open the airway.

The external nasal valve is the cartilaginous vestibule that serves as the entrance to the nose. It may become obstructed by extrinsic factors, such as foreign bodies, or intrinsic factors, such as weak or collapsed LLCs, cicatricial narrowing, or a loss of vestibular skin. Cartilage grafting (alar batten grafts, lateral crural strut grafts), soft-tissue grafting (mucosal, skin, or composite grafts), lysis of adhesions, or scar revision may be necessary to address the underlying etiology of the obstruction.

PREOPERATIVE ASSESSMENT

The Initial Consultation

Gunter and Gorney (11,12) have both commented on “danger signs” that may be exhibited by certain patients during the preoperative evaluation. Gorney relates patient concern to the actual degree of deformity (Fig. 10). Appropriate surgical candidates are considered to be those patients whose degree of concern is proportionate to their degree of deformity. However, those patients with a degree of concern that exceeds their actual degree of deformity often have an unrealistic expectation level of the ability of the operation to produce the desired result. Consequently, these patients should be avoided. Ultimately, however, if the level of skill and expertise required to perform the rhinoplasty exceeds one's ability, that patient should be referred to another qualified surgeon, regardless of the degree of deformity.

The use of computer imaging is a helpful adjunct in the planning of the operation as it provides the patient with a visual level of understanding of the anticipated outcome, although the images are not meant to guarantee surgical results. Standardized anterior, oblique, lateral,

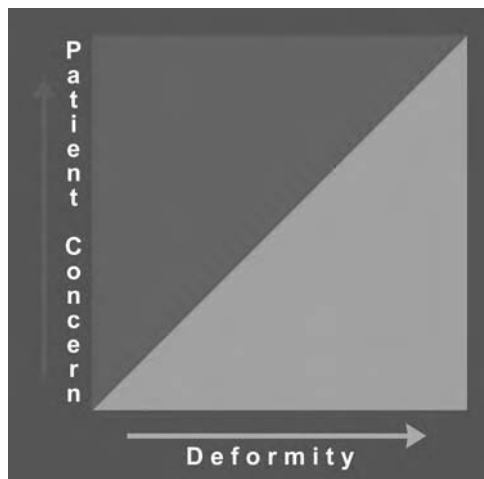


FIGURE 10 “Gorneygram” depicting the degree of patient concern to the degree of actual deformity.

and basal photographs should be taken prior to the operation in order to serve as a useful intra-operative reference.

Nasofacial Analysis

Accurate, systematic, and thorough nasofacial analysis is critical in order to determine the subsequent operative plan. The nose must not only be looked at in isolation, but also with respect to the rest of the face in order to create or preserve overall facial balance and harmony. It is also necessary to evaluate the patient preoperatively for any natural facial asymmetries so that the patient gains a better understanding of exactly what was present before any operative intervention.

The skin type, thickness, and texture are evaluated first. As previously mentioned, this is important because thicker, more sebaceous skin will require more aggressive modification of the underlying osseocartilaginous framework as changes tend to be camouflaged, whereas thinner skin will tend to show even minor changes.

The nasofacial analysis then proceeds in a systematic, methodical fashion. Below are some of the routine relationships and proportions that we use when analyzing the rhinoplasty patient. These are generally for the Caucasian female, but can be modified depending on the ethnicity and gender of the patient (13,14). It is important to remember that these proportions are general guidelines. Each nose should be individualized to the patient in order to achieve optimal nasofacial balance and harmony.

1. We start by dividing the face into thirds using horizontal lines tangent to the hairline, brow (at the level of the supraorbital notch), nasal base, and chin (menton). The upper third (between the hairline and the brow) is the most variable, as it depends on the hairline and hairstyle, and therefore is the least important. The middle third lies between the brow and nasal base. The lower third of the face can be subdivided into thirds by visualizing a horizontal line between the oral commissures (stomion). The upper third of this subdivision lies between the nasal base and the oral commissures, and the lower two-thirds between the commissures and the menton (Fig. 11A and B). Deviation from these proportions may signal an underlying craniofacial anomaly, such as vertical maxillary excess or maxillary hypoplasia, that may need to be addressed prior to rhinoplasty. The foundation must be sound before the nose that is to be constructed is addressed.
2. The nasal length (radix to tip, or R-T) should be equivalent to the stomion-to-menton distance (S-M) (Fig. 12).
3. The lip–chin relationship is assessed next by dropping a vertical line from a point one-half the ideal nasal length tangent to the vermilion of the upper lip. The lower lip should lie approximately 2 mm behind this line. The ideal chin position varies with gender, with the chin lying slightly posterior to the lower lip in women, but equal to the lower lip in men.

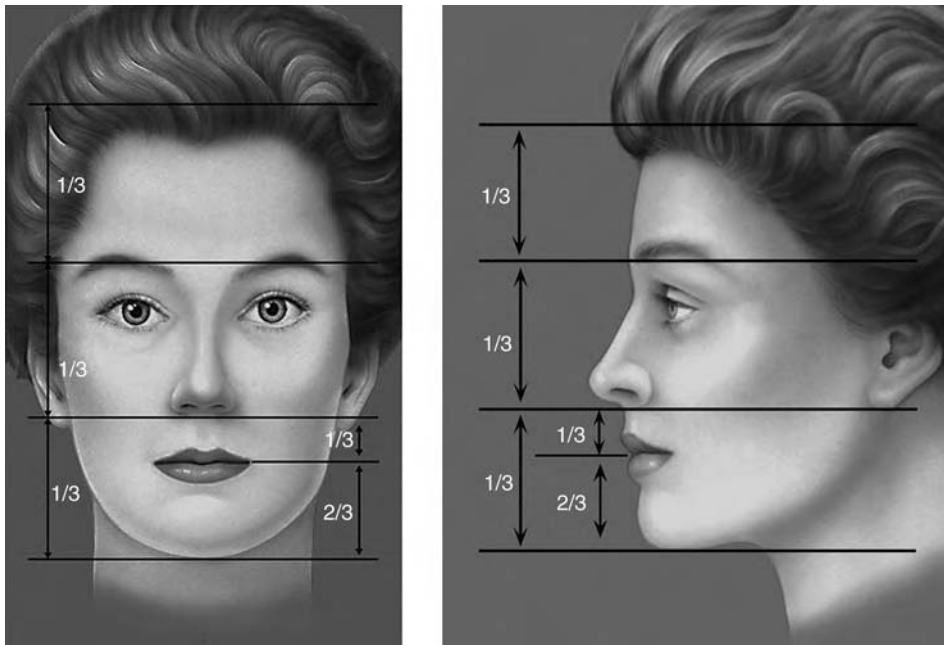


FIGURE 11 The face is divided into thirds with the top 1/3 being its most variable and the least important; the bottom third is further subdivided into thirds with the stomion as the divider.

Orthodontics, orthognathic surgery, or a chin implant may be necessary to improve overall facial harmony if there is a discrepancy in these relationships (Fig. 13).

4. The nose itself is now addressed from the anteroposterior view. A vertical line is drawn from the mid-glabella area to the menton, bisecting the nasal ridge, upper lip, Cupid's bow, and central incisors (if the patient has normal occlusion). Any nasal deviation from this line is likely to require septal surgery (Fig. 14).
5. The curvilinear dorsal aesthetic lines are traced from their origin at the supraorbital ridges toward their convergence at the level of the medial canthal ligaments. From here, they

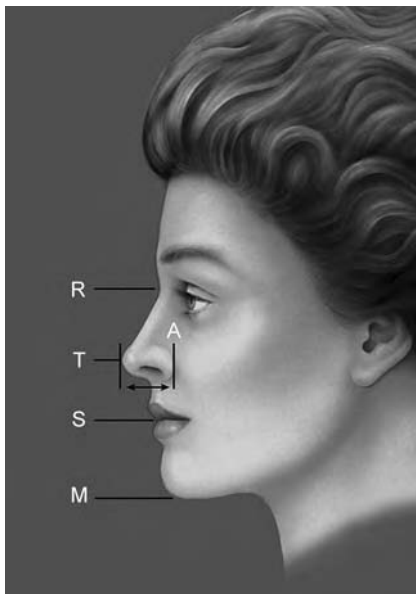


FIGURE 12 R-T (radix-to-tip) should be equal to S-M (stomion-to-menton).



FIGURE 13 In women, the chin should be 2 mm behind a vertical line dropped from one-half the ideal nasal length tangent to the upper tip vermillion. In men, the chin should about this line.

flare slightly at the keystone area and then track down to the tip-defining points, slightly diverging from each other along the dorsum during their course. The ideal width of the dorsal aesthetic lines should be approximately equivalent to the width of either the tip defining points or the interphiltral distance (Fig. 15).

6. The normal alar base width is equivalent to the intercanthal distance, or the width of one eye. If the alar base width is greater than the intercanthal distance, the underlying etiology should be examined. If the discrepancy is the result of a narrow intercanthal distance, it is better to maintain a slightly wider alar base. If there is true increased interalar width a nostril sill resection may be indicated. If the increase in width is secondary to alar flaring (greater than 2–3 mm outside the alar base), an alar base resection should be considered. The bony base should equal approximately 80% of the alar base width (Fig 16). If the bony base is greater than 80% of the alar base width, osteotomies may be required. Avoid over-narrowing the dorsum in males as this can lead to an “overfeminized” look.
7. The alar rims should be examined for symmetry. They should normally flare slightly outward in an inferolateral direction (Fig. 17).
8. The tip is assessed by drawing two equilateral triangles with their bases opposed (Fig. 18). The supratip break, tip-defining points, and columellar-lobular angle serve as landmarks



FIGURE 14 A bisecting line from mid-glabella to menton is used to determine nasal deviation.



FIGURE 15 The ideal dorsal aesthetic lines are well-defined and should approach the width of either the tip-defining points or the interphiltral distance.

to draw these. If these triangles are asymmetric, the patient will likely require tip modification.

9. The final assessment on frontal view is of the outline of the alar rims and the columella. Normally, this outline should resemble a seagull in gentle flight. If the angles are too steep, the patient likely has an increased infratip lobular height. Conversely, if the angle/curve is too flattened, it is likely the patient has decreased columellar show, which may require columellar and/or alar rim modification (Fig. 19).
10. The basal view of the nose is addressed next, where both the outline of the nasal base and the nostril itself is analyzed. The outline of the nasal base should describe an equilateral triangle with a lobule-to-nostril ratio of 1:2 (Fig. 20). The nostril itself should have a teardrop-like geometry, with the long axis oriented in a slight medial direction (from base to apex).
11. Attention is then turned to the lateral view, beginning with the analysis of the nasofrontal angle. This angle connects the brow and nasal dorsum through a soft concave curve. The



FIGURE 16 The bony base should be approximately 80% of the alar base width.



FIGURE 17 The alar rims should normally flare slightly outward in an inferolateral direction.



FIGURE 18 The evaluation is analyzed through the use of double-opposing equilateral triangles.



FIGURE 19 The outline of the alar rims and columella should resemble a seagull in gentle flight.

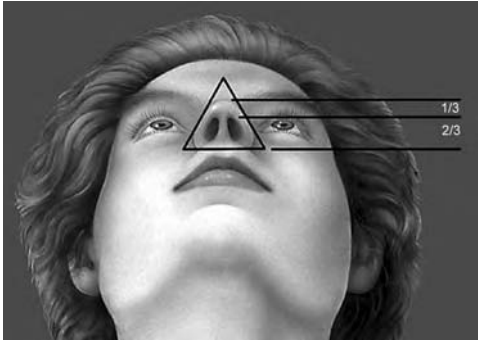


FIGURE 20 The lobule-to-nostril ratio is usually 1:2.

apex of this angle (radix) should lie between the supratarsal fold and the upper lid lashes, with the eyes in natural horizontal gaze. This angle can vary between 128° to 140° , but is ideally approximately 134° in females and 130° in males.

12. It is important to note that the perceived nasal length and tip projection can be altered by the position of the nasofrontal angle. For instance, the nose may appear more elongated if the nasofrontal angle is positioned more anteriorly and superiorly than normal. In this instance, the nasofacial angle (as defined by the junction of the nasal dorsum with the vertical facial plane) is decreased and the tip projection will appear diminished (yellow line). Conversely, the nose can appear shorter if the nasofrontal angle is positioned too posteriorly and/or inferiorly. In this case, the tip may also appear more projecting (red line) (Fig. 21). Ideally, the nasofacial angle should measure 32° to 37° .
13. While still analyzing the lateral view, tip projection is addressed. This can be done in two ways. The first is to draw a horizontal line from the alar–cheek junction to the tip of the nose. The distance between these points should equal two things: (i) the alar base width, and (ii) $0.67 \times \text{RT}$ (radix–tip) (Fig. 22). The second way to assess tip projection is to examine how much of the tip lies anterior to a vertical line tangent to the most projecting part of the upper lip vermilion. If 50% to 60% of the tip lies anterior to this line, projection is considered normal. If the tip projection is outside of these proportions, it likely will require tip modification (Fig. 23).
14. The dorsum is analyzed next by drawing a line from the radix to the tip-defining points. In women, the ideal aesthetic nasal dorsum should lie approximately 2 mm behind and parallel to this line, but in men, it should approach this line to avoid feminizing the nose (Fig. 24).



FIGURE 21 The position of the nasofrontal angle can affect the perceived nasal length.

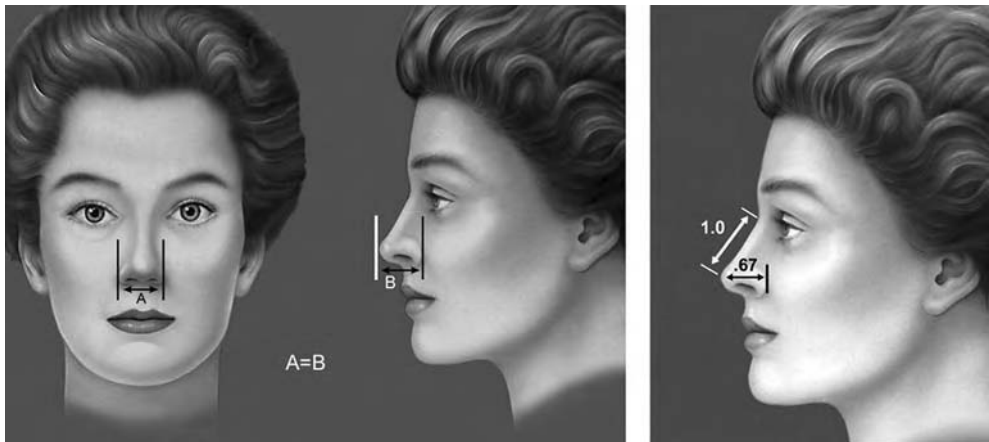


FIGURE 22 Nasal tip projection should equal $0.67 \times$ the nasal length or equal to the alar base width.

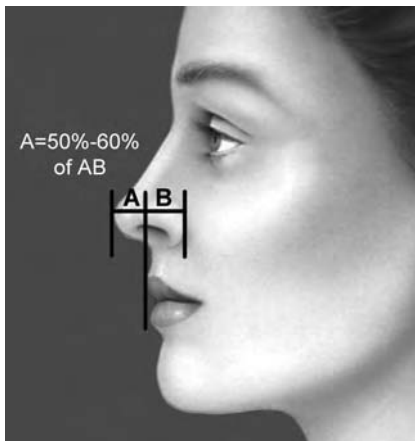


FIGURE 23 Tip projection can also be considered normal if 50% to 60% of the tip lies anterior to a vertical line abutting the upper tip vermilion.

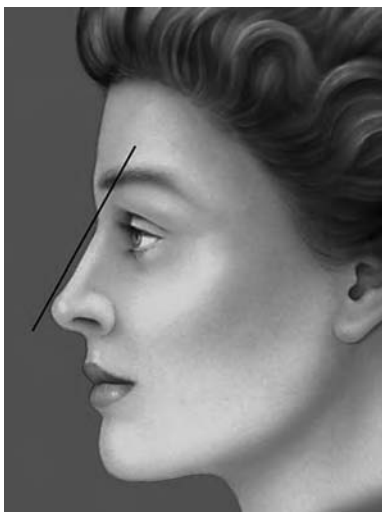


FIGURE 24 In women, the dorsum should lie approximately 2 mm behind a line drawn from the radix to the tip-defining points.

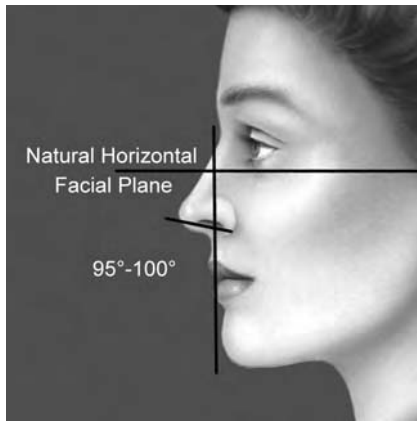


FIGURE 25 The nasolabial angle is usually 95°–100° in women and 90°–95° in men.

15. The degree of supratip break is also evaluated on the lateral view. This break helps to define the nose and separate the tip from the dorsum. A slight supratip break is preferred in women but not in men.
16. The degree of tip rotation is assessed by evaluating the nasolabial angle, which is the angle formed between a line coursing through the most anterior and posterior edges of the nostril and a plumb line dropped perpendicular to the natural horizontal facial plane (Fig. 25). This angle is usually 95° to 100° in women and between 90° and 95° in men.
17. The nasolabial angle is often confused with the columellar-labial angle, which is formed at the junction of the columella with the infratip lobule (Fig. 26). This angle is normally 30° to 45°. A prominent caudal septum can cause increased fullness in this area, which can give the illusion of increased rotation, despite a normal nasolabial angle.
18. The alar–columellar relationship is assessed by drawing a line through the long axis of the nostril and a second, perpendicular line drawn from alar rim to columellar rim that bisects this axis. If the alar–columellar relationship is normal, the distance from the alar rim (“point A”) to the long axis line (“point B”) should equal the distance between the long axis line to the columellar rim (“point C”) ($AB = BC \approx 2$ mm) (Fig. 27). If abnormal, the deformity can be stratified into six classes (15,16). Classes I to III describe increased columellar show, while IV–VI demonstrate decreased columellar show. The treatment of the discrepancy varies by class.

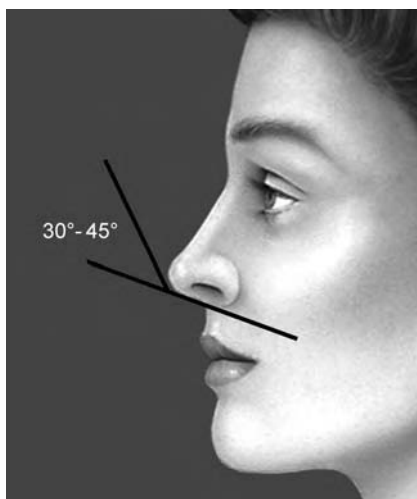


FIGURE 26 The columellar-labial angle, different from the nasolabial angle, is usually 30°–45°.

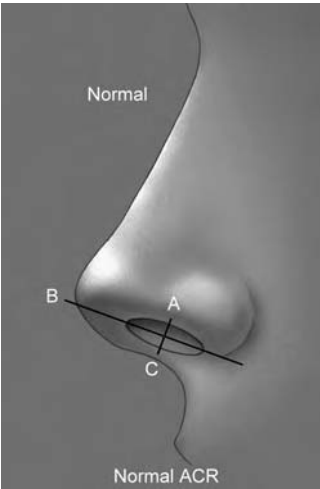


FIGURE 27 Landmarks to determine the alar–columnar relationship.

The final critical part of the preoperative analysis is the intranasal examination, which is performed with a nasal speculum, headlight, and vasoconstriction. Deformities or abnormalities of the septum, turbinates, and internal nasal valve are evaluated. If turbinate hypertrophy is identified, the underlying etiology should be investigated and a detailed history taken, as the enlargement may be either congenital or acquired. If acquired, it may be the result of autonomic, environmental, medical, or anatomic factors (Table 1).

OPERATIVE TECHNIQUE
Type of Approach

There are two schools of modern rhinoplasty—those who prefer the open approach and those who prefer the closed. While both approaches have their advantages and disadvantages, it is

TABLE 1 Causes of Inferior Turbinate Hypertrophy. Deviation of the Septum May Also Be Congenital.

Causes of ITH	
Congenital	Acquired
Autonomic	Environmental
Medical	Anatomic
Vasomotor rhinitis Sexual stimulation Emotions	Allergic rhinitis Dust Tobacco
Inflammatory Hyperthyroidism Pregnancy Rhinitis medicamentosa	Associated with deviated nasal septum

Abbreviation: ITH, inferior turbinate hypertrophy

TABLE 2 Rationale for Open Rhinoplasty

Distinct advantages	Potential disadvantages
Binocular visualization	External nasal incision
Evaluation of complete deformity without distortion	(transcolumellar scar)
Precise diagnosis and correction of deformities	Prolonged operative time
Allows use of both hands	Protracted nasal tip edema
More options with original tissues and cartilage grafts	Columellar incision separation
Direct control of bleeding with electrocautery	Delayed wound healing
Suture stabilization of grafts (invisible and visible)	

important to be familiar with both. The experienced surgeon will tailor the approach to the patient's anatomic deformity. Regardless of the approach, however, ultimately the modifications made to the underlying framework supersede which incision type is used.

The rationale for the open approach is summarized in Table 2.

A summary of the benefits of the endonasal (closed) approach is listed below in Table 3.

Generally, we prefer the open approach as it affords full exposure of the nasal framework resulting in an accurate diagnosis of all the potential causes of either the nasal airway obstruction or the etiology of the cosmetic deformity. Furthermore, precise manipulation of the various structures can be performed and the dynamic interplay between these structures appreciated, giving us reproducible results. We strongly encourage the use of the open approach in three particular circumstances: (i) post-traumatic deformities, where complete release of all intrinsic and extrinsic deforming forces is necessary, (ii) secondary/revisional surgery, and (iii) when complex tip modifications are necessary.

We find the "closed" approach lends itself well to patients who have either an isolated dorsal hump deformity or where there is minimal change needed to modify the tip structure. In these instances, we prefer access through a marginal incision. This is combined with an intercartilaginous incision in cases of minor tip refinement in order to allow for adequate cartilage delivery and exposure. A hemitransfixion or transfixion incision is used if the caudal septum needs to be addressed.

TABLE 3 Advantages/Disadvantages for Endonasal Approach

Advantages
Leaves no external scar
Limits dissection to areas needing modification
Permits creation of precise pocket so graft material fits exactly, without need for fixation
Allows percutaneous fixation when large pockets are made
Promotes healing by maintaining vascular bridges
Encourages accurate preoperative diagnosis and planning
Produces minimal postsurgical edema
Reduces operating time
Results in fast patient recovery
Creates intact tip graft pocket
Allows composite grafting to alar rims
Disadvantages
Requires experience and great reliance on accurate preoperative diagnosis
Prohibits simultaneous visualization of surgical field by teaching surgeon and students
Does not allow direct visualization of nasal anatomy
Makes dissection of alar cartilages difficult, particularly in cases of malposition

TABLE 4 Areas to Infiltrate with Local Anesthesia. Location/Volume Distribution of 1% Lidocaine with 1:100,000 Epinephrine.

Location	Amount (mL)
Vestibules/aperture	2
Dorsum	1
Lateral walls	2
Tip/columella	2
Distal septum	2
Inferior turbinates	1
	10

Anesthesia/Preoperative Preparation

Although local anesthesia with IV sedation may be used, we prefer general anesthesia. After induction, the nasal vestibules are prepared by clipping the nasal vibrissae and swabbing the entire nostril with Betadine solution. Before injecting local anesthetic, we mark the line of our anticipated incision (transcolumellar stairstep, if using an open approach) so as not to distort the anatomy. We then inject approximately 10cc of 1% lidocaine with 1:100,000 epinephrine into the intranasal mucosa, along the septum, and into soft-tissue envelope (Table 4). Additional local is used on the inferior turbinates when we anticipate on performing an inferior turbinoplasty.

After injection, cottonoid pledgets soaked with a local vasoconstrictor solution are placed, three per nare. This is done to shrink the nasal mucosa to facilitate exposure and minimize blood loss. While our preference is oxymetolazone (Afrin), 4% cocaine may be used as well. A throat pack is carefully placed in the posterior oropharynx to prevent inadvertent digestion of blood during surgery, which helps prevent postoperative nausea and vomiting. At this point, the patient is prepped and draped for surgery.

Incision—Closed Approach

There are two basic techniques, nondelivery and delivery, used for access in endonasal rhinoplasty. The nondelivery approach can be performed using either a cartilage-splitting (transcartilaginous) incision or an eversion (or retrograde) incision. The transcartilaginous incision is made by incising several millimeters cephalad to the caudal margin of the lateral/middle crura. This preserves a rim strip to support the ala (Fig. 28). Exposure is facilitated by double hook retraction combined with digital alar eversion. The cartilage is then exposed for resection by dissecting the vestibular skin off of the cartilage. In the eversion approach, rather than going through the cartilage, the vestibular incision is made at the cephalic-most margin of the LLC (Fig. 29). The same exposure technique is used as described above. The theoretical advantage to this incision is that it maintains the caudal alar margins and prevents potential scar contracture deformities in this area.

The delivery approach is used in cases where moderate-complexity tip modifications are necessary. This is especially true in cases where there is significant tip bifidity. Again, the cartilaginous margins are delineated with double hook retraction in the ala and digital

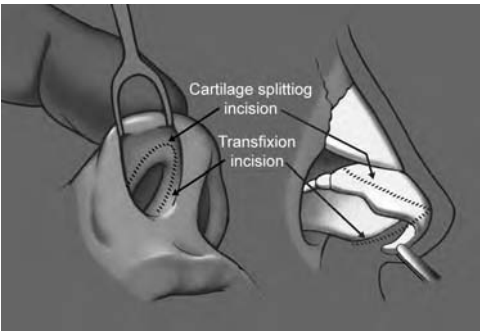


FIGURE 28 Cartilage-splitting incisions for closed rhinoplasty.



FIGURE 29 The eversion approach to closed rhinoplasty.

counterpressure, and a 15-blade scalpel is used to create an intercartilaginous incision starting just above the cephalic margin of the lateral crus. The incision is carried lateral to medial approximately 2 mm caudal and parallel to the limen vestibule. Subsequently, a marginal incision is created along the caudal margin of the LLC, from lateral crus to medial crus, ending at the columellar–lobular junction (Fig. 30). The soft tissue is then dissected off of the cartilage in a plan just above the perichondrium, including over the dorsal cartilaginous septum. The same procedure is repeated on the contralateral side, and the two incisions are connected in the midline over the anterior septal angle, ending in a hemitransfixion incision. Of course, this can be extended to a full transfixion incision, if indicated. The LLC is then dissected free from the surrounding tissues and “delivered” outside the incision. The incisions may be extended and the soft tissue undermined more aggressively if there is difficulty delivering the cartilages. Modifications may be made once the cartilages and domes are delivered.

Incision—Open Approach

We prefer a transcolumellar stair-step incision across the narrowest portion of the columella. The advantages of the stair-step include the provision of landmarks for accurate closure, the prevention of linear scar contracture, and its ability to camouflage the scar (Fig. 31).

Infracartilaginous extensions are then performed bilaterally, beginning from lateral to medial along the caudal border of the LLC. These incisions meet the transcolumellar incision to complete this approach. Exposure during this dissection is facilitated by double-hook alar eversion and digital counterpressure (Fig. 32).

It is important to take your time during this portion of the procedure, as most mistakes are made trying to obtain exposure. Furthermore, the incisions should be kept superficial and the caudal border of the LLC should be identified prior to cutting to prevent injury to the underlying cartilages.

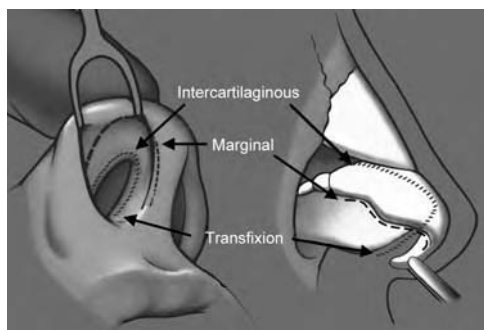


FIGURE 30 Incisions frequently used for cartilage delivery in closed rhinoplasty.



FIGURE 31 The transcolumnellar incision for open rhinoplasty.

Skin Envelope Dissection

Extreme care should be taken during the exposure of the nasal framework so as not to injure the underlying cartilages. The dissection should be carried out in the suprapraperichondrial/submusculoaponeurotic plane in order to avoid injury to the arterial, venous, and lymphatic supply to the nose. If performed properly, there should be no residual soft tissue remaining on the LLCs. This dissection is continued superiorly to expose the cartilaginous dorsum and ULCs until the bony pyramid is encountered. At this point, a limited subperiosteal dissection is performed just over the area of the bony dorsal hump that needs to be addressed. Care is taken to avoid disruption of all of the periosteal attachments to the nasal bones, as this can destabilize the area and lead to prolonged wound healing and potential nasal bone malposition (Fig. 33). Care is also taken to assure that the ULCs are not detached from the nasal bones by accidental dissection under the nasal bones (rather than on top).

Nasal Dorsum

Our preferred technique is the component dorsal reduction, which includes separation of the ULCs from the septum, separate incremental reduction of both the cartilaginous septum and the bony dorsal deformity, and the verification of acceptable final contour by palpation.



FIGURE 32 Technique of double-hook alar eversion and digital counterpressure.



FIGURE 33 Limited subperiosteal dissection is performed over the nasal bones.

1. Separation of the ULCs from the septum. The component dorsal reduction technique begins with the creation of bilateral superior subperichondrial tunnels in order to minimize mucosal trauma resulting in potential internal nasal valve stenosis or vestibular webbing. This is done by elevating the mucoperichondrium of the dorsal septum in a caudocephalad direction with a Cottle elevator until the nasal bones are reached. The transverse processes of the ULCs are then sharply separated from the septum using a 15-blade scalpel (without damaging the mucosa) (Fig. 34A and B).
2. Incremental component cartilaginous dorsal septal reduction. At this point, the cartilaginous dorsal septum is separated into three components—the septum centrally, and the transverse portions of the ULC laterally. The cartilaginous dorsum is then reduced in incremental fashion by resecting the dorsal hump deformity with either a sharp scalpel or scissors in serial fashion. This is done under direct vision. Care is taken to avoid damage to the adjacent ULCs. In rare cases, the ULCs may require resection, though this is not routine in our practice. If required, it must be performed cautiously, as overresection of the ULCs can cause internal nasal valve collapse and long-term dorsal irregularity (17). Maintaining the transverse portions of the ULC also preserves the dorsal aesthetic lines. If the septum and ULCs were taken down

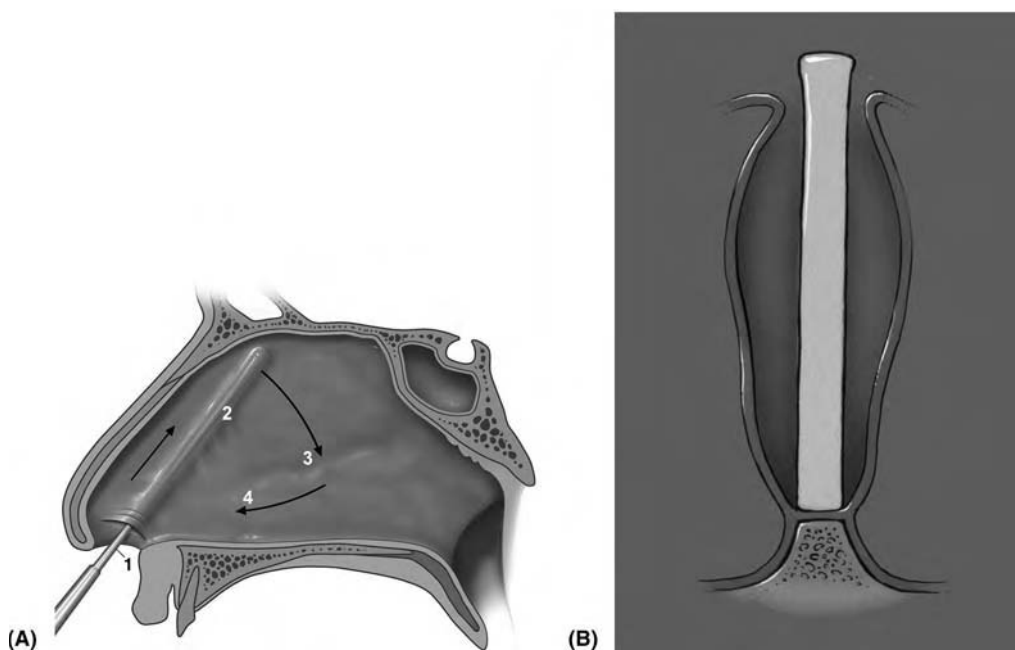


FIGURE 34 The development of bilateral subperichondrial tunnels/pockets allows for optimal exposure to the septum for component dorsal reduction.



FIGURE 35 Careful incremental rasping of the bony dorsal hump.

en bloc (not in component fashion), a rounded dorsum would result. Furthermore, an inverted-V deformity could result if the ULCs were resected to a greater extent than the septum.

3. Component bony dorsum reduction. Large humps (generally >5 mm) are reduced either by a power burr with a dorsal skin protector or a guarded 8 mm osteotome. Smaller humps can be addressed with a sharp rasp (we prefer a down-biting diamond rasp). The rasping is done in a controlled, methodical fashion, proceeding along the left and right dorsal aesthetic lines, and then centrally using the nondominant thumb and index finger for maximal control (Fig. 35). It is important to maintain a slightly oblique bias when rasping in order to prevent mechanical avulsion of the ULCs from the nasal bones.
4. Verification of final contour by palpation. The three-point dorsal palpation test, performed with a saline-moistened dominant index fingertip, is used to gently palpate the left and right dorsal aesthetic lines, as well as centrally, in order to ascertain if there are any residual dorsal irregularities or contour depressions (Fig. 36). This maneuver is performed repeatedly throughout this process (after redraping the skin envelope).

Septal Reconstruction/Cartilage Graft Harvest

The septum is harvested if there is a septal deformity or if cartilage is needed for graft construction. Septal cartilage is ideal for cartilage graft harvesting in rhinoplasty because of its minimal donor site morbidity and close geographic proximity to the operating field.

A Killian or hemitransfixion incision is generally used in the closed (endonasal) approach as a complete transfixion incision can lead to decreased tip projection, especially if dissection is carried down over the anterior nasal spine.

In the open approach, the anterior septal angle is exposed by separating the middle crura and incising the interdomal suspensory ligament. The septal perichondrium is incised with a



FIGURE 36 The three-point dorsal palpation test.

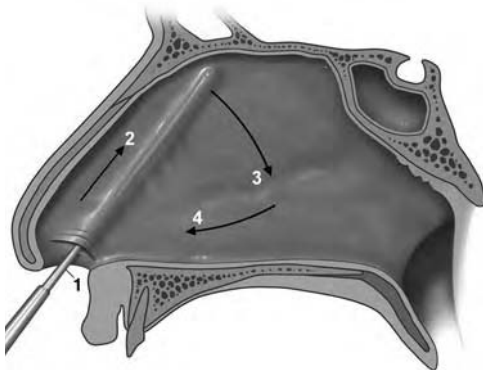


FIGURE 37 Septal dissection.

15-blade scalpel exposing the distinctive bluish-gray underlying cartilage. A Cottle elevator is then used to carry the dissection in a subperichondrial plane posteriorly to the perpendicular plate of the ethmoid down to the nasal floor and across the face of the septum (Fig. 37). This subperichondrial dissection should proceed easily if performed in the correct plane. However, the dissection should proceed with caution at the junction of the cartilaginous and bony septum, as the overlying mucoperichondrium is more adherent, and mucosal perforation is more likely. The same dissection is then performed on the contralateral side, and the entire septum is examined using a Vienna speculum in order to identify deformities and to help achieve exposure for the septal harvest.

It is important to maintain the stability of the cartilaginous framework by preserving an L-strut with 10 mm of dorsal septum and 10 mm of caudal septum (Fig. 38). The harvested cartilage should be preserved in saline to prevent desiccation. Residual deviations in the ethmoid or vomer are rongeured or resected and any mucosal perforations are repaired.

Inferior Turbinoplasty

An inferior turbinoplasty is performed in those patients with inferior turbinate hypertrophy causing symptomatic nasal airway obstruction. There are various ways this can be performed,

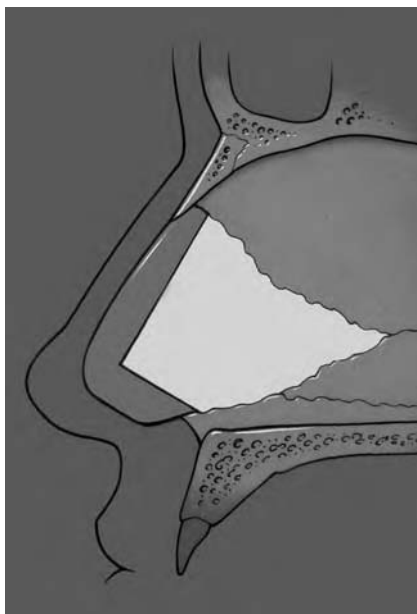


FIGURE 38 It is important to preserve a 10 mm dorsal and caudal L-strut.

including turbinate outfracture, submucous morselization of the turbinate bone, and submucous resection of the anterior 1/3–1/2 of the inferior turbinate (9,18). The submucous resection technique begins with the development of medial mucoperiosteal flaps, which exposes the conchal bone. The anterior portion of the conchal bone is resected, as bleeding complications can occur with posterior resection. The flaps are replaced after this resection without the need for suture repair (Fig. 39).

Cephalic Trim

Indications for a cephalic trim include the need for tip rotation, medialization of the tip-defining points, and/or when the tip requires better refinement and definition as in the case of the boxy or bulbous tip. A caliper is used to measure out a 6 mm rim strip of the caudal margin of the LLC that is to be preserved. Subsequently, the cephalic portion of the middle and lateral crura is resected and preserved for possible use as a graft later in the case (Fig. 40).

Spreader Grafts

Spreader grafts are extraordinarily versatile. They have many indications and applications, such as to help stent open the internal valve, to stabilize the septum, and to preserve or enhance the dorsal aesthetic lines (19,20) (Fig. 41). These grafts, usually obtained from septal cartilage, are usually fashioned to measure approximately 25–30 by 3 mm. They can also be made longer and placed in such a way as to project past the anterior septal angle, effectively lengthening the nose. They can also be positioned more anteriorly (“visible”) along the septum in order to recreate stronger dorsal aesthetic lines or can be positioned lower (“invisible”) for septal support or internal valve stenting (Fig. 42A and B). The grafts are secured with 5-0 PDS in horizontal mattress fashion.

Tip Modification

Altering Tip Projection

Tip projection is affected by (21):

1. The supporting ligament between the anterior septal angle and the overlying dermis
2. The length and strength of the LLCs
3. The suspensory ligament bridging the anterior septal angle
4. The fibrous connections between the ULCs and LLCs (and septum)
5. The abutment of the cartilages with the pyriform aperture
6. The anterior septal angle

Alteration of any of these anatomic structures can result in incremental changes in tip projection.

A graduated algorithm to alter tip projection is used that is based on nondestructive techniques. The algorithm begins with suture techniques, which can reliably deliver an increase of 1 to 2 mm of tip projection. The choice of suture material is surgeon-dependent, though the underlying premise is to select a material that will hold the cartilage in its altered position long enough to allow for the natural fibrotic reaction to solidify the result.

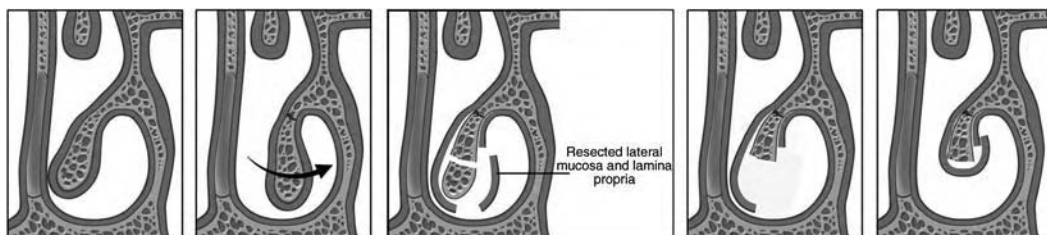


FIGURE 39 Technique of submucosal resection of the inferior turbinate.

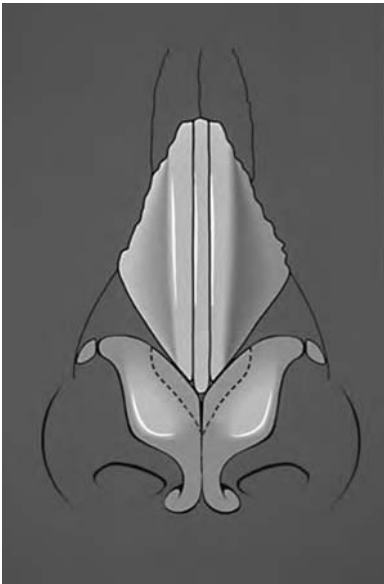


FIGURE 40 Cephalic trim leaving at least a 6 mm rim strip.

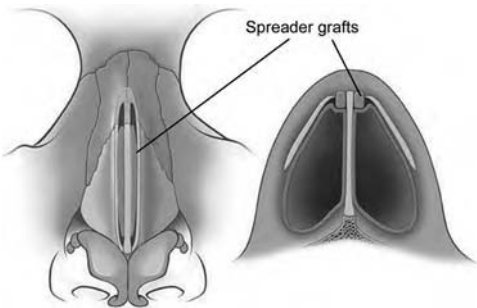


FIGURE 41 Spreader grafts may be helpful to stent open the internal nasal valve, stabilize the septum, or preserve/enhance the dorsal aesthetic lines.

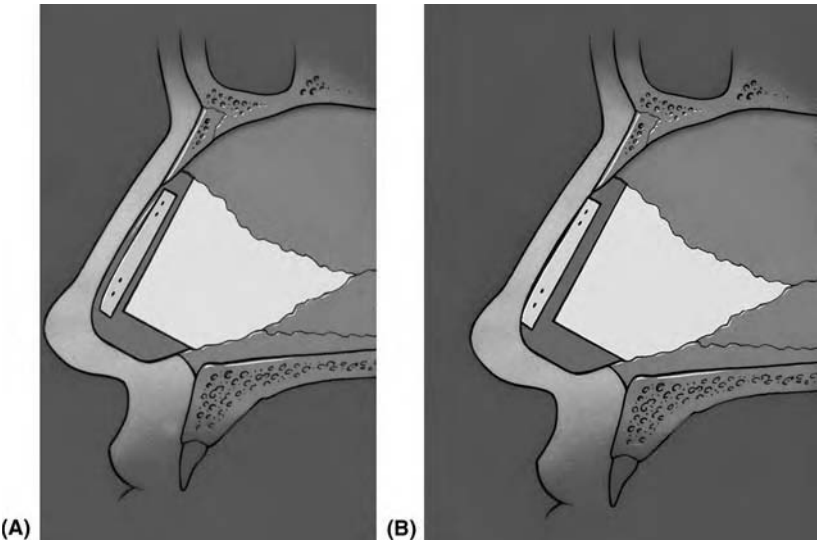


FIGURE 42 Spreader grafts may be placed in a “visible” (A) or “invisible” (B) position, depending on the desired effect.

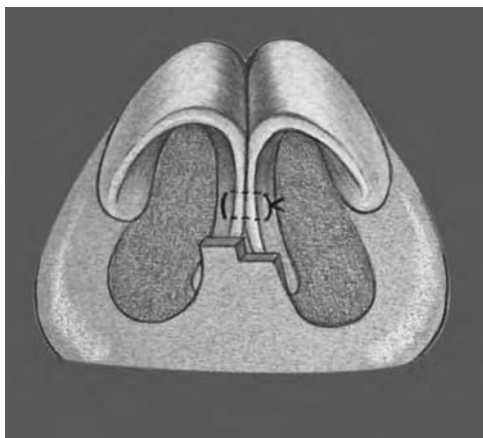


FIGURE 43 Medial crural sutures.

There are four general types of suture techniques used to alter projection:

- Medial crural
- Medial crural septal
- Interdomal
- Transdomal

Medial crural sutures can be used to unify the medial crura of the LLCs and to rectify flaring of the medial/middle crura, thereby effecting a limited increase in projection (Fig. 43). They are also frequently used to help stabilize a columellar strut.

Medial crural septal sutures can alter both projection and rotation by anchoring the medial crura to the caudal septum. These sutures are also often used in conjunction with columellar struts (Fig. 44).

Interdomal sutures can increase both tip refinement and tip projection. They serve to narrow the interdomal distance by approximating the medial/middle crura. Sutures are placed in mattress fashion, and can be tightened to a variable degree in order to achieve the desired result (Fig. 45).

Transdomal sutures can also affect both tip refinement and projection. These mattress-type sutures are placed across the dome of the middle crura after hydrodissection of the

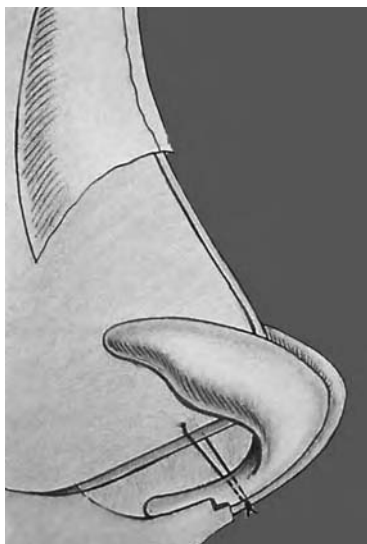


FIGURE 44 Medial crural septal sutures.

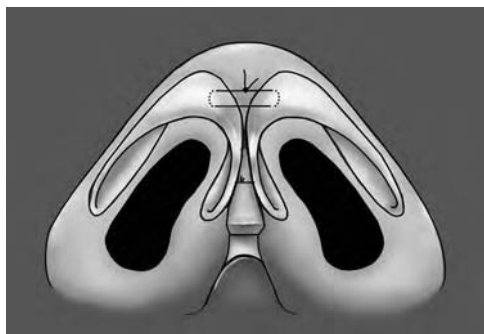


FIGURE 45 Interdomal sutures.

underlying mucoperichondrium from the cartilage in order to help prevent inadvertent incorporation into the suture bite (Fig. 46). Knots are left on the medial aspect of the dome and one end may be left long on each side, which can be used to tie the transdomal sutures together (i.e., an interdomal suture) in order to narrow the tip-defining points. It is important, however, to avoid overtightening of this suture, which will result in an unnaturally sharp tip-defining point. They may be also be placed asymmetrically in order to correct anatomic differences that may exist from side to side.

The placement of a columellar strut is the second step in the algorithm of tip projection alteration. This strut, usually fashioned from septal cartilage, can be placed in a “fixed” or a “floating” fashion, depending on whether or not it is secured to the anterior maxilla or not (Fig. 47A and B). This strut controls the columellar profile as well as supports tip projection. A pocket is dissected between the medial crura and the strut is inserted. Its final position is set by gently retracting the medial crura anteriorly by a double-hook and gauging the desired amount of tip projection. This configuration is temporarily stabilized with a transversely placed 25-gauge needle and then sutured into position by medial crural sutures (described above). Additional medial crural sutures can then be placed, if necessary, to control medial crural flaring.

Tip grafts are the final step in the algorithm for graduated tip modification if more tip projection or definition is desired after the preceding maneuvers. These grafts may take several forms, but have a tendency to be visible regardless of the specific type used, so their use is reserved only for the patient in which the prior, more predictable, methods do not result in satisfactory tip projection. There are three general types of tip grafts:

- Onlay tip grafts
- Infratip lobular graft
- Columellar-tip graft

The onlay tip graft is usually placed over the dome of the middle crura, and can be fashioned from any type of cartilage, although we find the cartilage obtained from the cephalic trim harvest (if performed) works exceptionally well (Fig. 48).

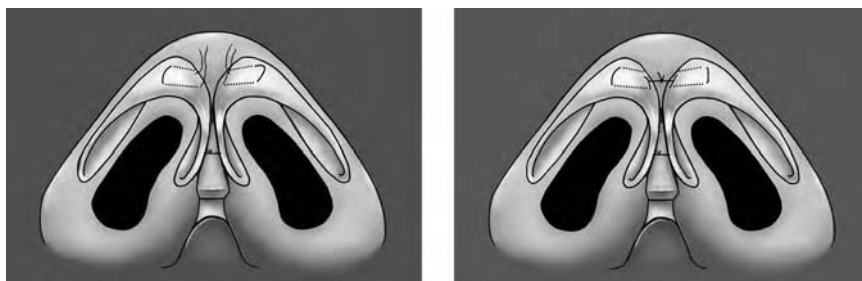


FIGURE 46 Transdomal sutures with one suture tail left long to tie together to perform an interdomal suture.

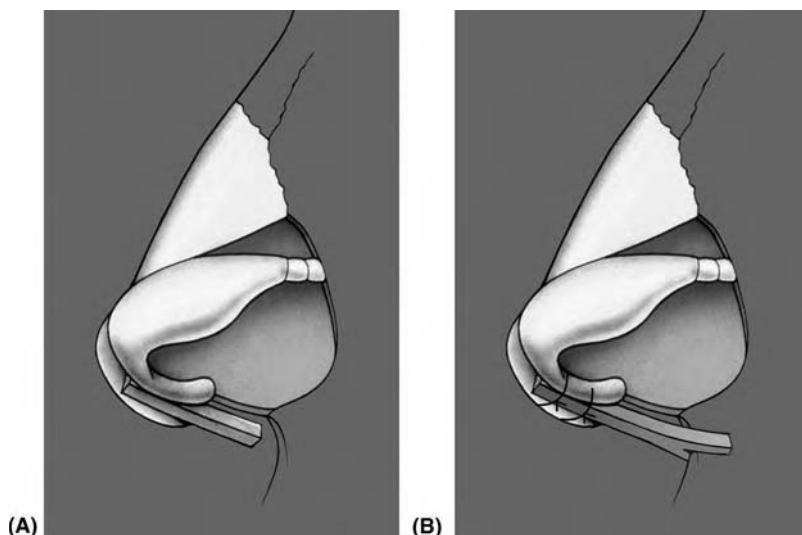


FIGURE 47 The columellar strut may be placed in a “floating” (A) or “fixed” (B) position.

The infratip lobular graft is a shield-shaped graft used to graft increase infratip lobular definition and projection. It is positioned with its superior margin overlying the dome/tip-defining points and extends inferiorly a variable distance (usually 10–12 mm). It is fashioned with rounded graft edges in order to avoid a visible and palpable step-off (Fig. 49).

The columellar-tip graft is generally used in difficult primary rhinoplasties, thick-skinned patients, and secondary rhinoplasties with inadequate tip projection. It is essentially a “combination” graft of the above-mentioned onlay tip graft and infratip lobular graft. Superiorly, it is anchored to the ULCs and inferiorly it is secured to the caudal margin of the medial crura (Fig. 50).

A thorough understanding of the anatomic basis of tip support is also required when trying to *decrease* nasal tip projection. For instance, in the open approach where the skin envelope has been undermined and the fibroelastic and ligamentous attachments have been disrupted, the primary means of decreasing tip projection lies in alteration of the length and



FIGURE 48 The onlay tip graft.

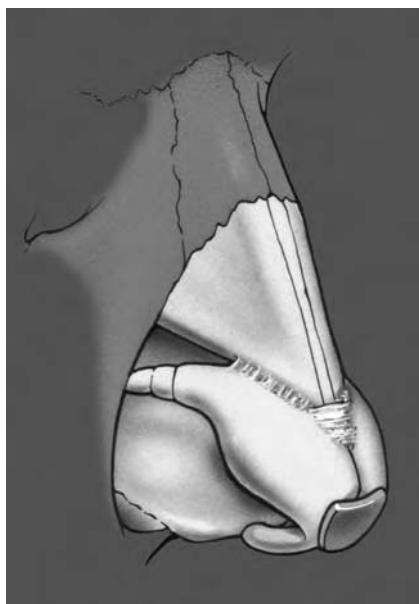


FIGURE 49 The infratip lobular graft.

strength of the LLCs. Several techniques, such as transection, setback, and resuturing of the medial or lateral crura, may be used to obtain the desired result. However, regardless of the technique used, it is important to recognize that if the tip projection is significantly decreased, alar flaring or columellar bowing may result. This, then, would require concomitant correction (Fig. 51).

Altering Tip Rotation

In order to alter tip rotation, the existing extrinsic forces stabilizing the tip at its current position must be released. The first step is usually to perform a cephalic trim, which separates the connection between the ULCs and LLCs (Fig. 52). Another technique is to resect a variable amount

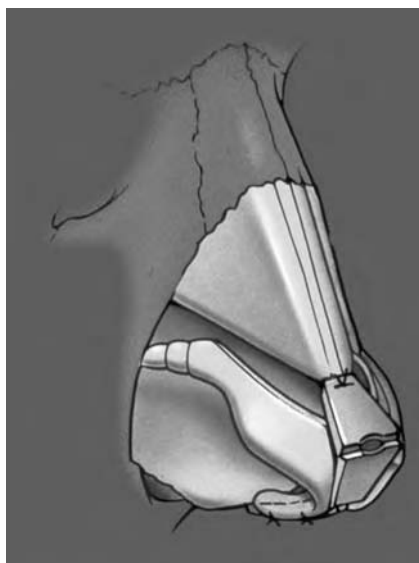


FIGURE 50 The columellar-tip graft, or “combination” graft.

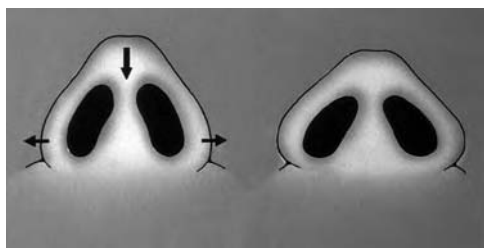


FIGURE 51 Alar flaring or columellar bowing may result from decreasing tip projection.

of the caudal septum. This releases tension on the nasal tip and allows for more cephalad rotation by transecting the fibrous attachments of the medial crura and the caudal septum (Fig. 53). This maneuver can also affect tip projection, as well. After the desired amount of tip rotation has been achieved, its position is maintained with suture techniques (medial crural septal sutures) and/or a columellar strut or septal extension graft.

It may be necessary to perform a limited resection of the nasal mucosa and membranous septum in order to maintain proper nasal balance and harmony, depending on the amount of tip (de)rotation.

Osteotomies

Several techniques exist in order to perform osteotomies, including medial, lateral, transverse, or a combination of the above. These can be performed via an external or internal approach, depending on surgeon preference.

Osteotomies are generally performed for the following reasons:

- To narrow the lateral walls of the nose
- To close an open-roof deformity (after dorsal hump reduction)
- To create symmetry by allowing for straightening of the nasal bony framework (22)

Contraindications include patients with short nasal bones, elderly patients with thin, fragile nasal bones, and patients with heavy eyeglasses (23,24).

Lateral osteotomies may be performed as “low-to-high,” “low-to-low,” or as a “double level” (Fig. 54). Furthermore, they may be combined with medial, transverse, or greenstick fractures of the upper bony segment. Regardless of the technique used, however, it is paramount to preserve Webster’s triangle. This bony triangular area of the caudal aspect of the maxillary frontal process near the internal valve is necessary for internal nasal valve support. Preservation of this triangle prevents functional nasal airway obstruction from internal valve collapse (Fig. 55).

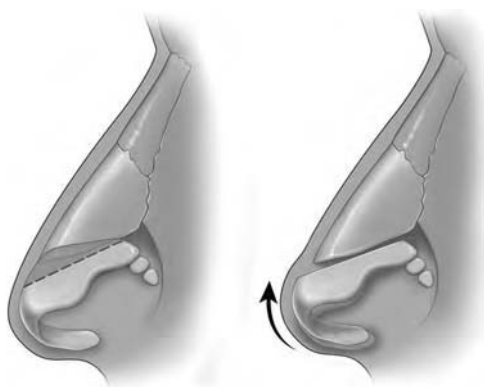


FIGURE 52 Cephalic trim to affect trip rotation.

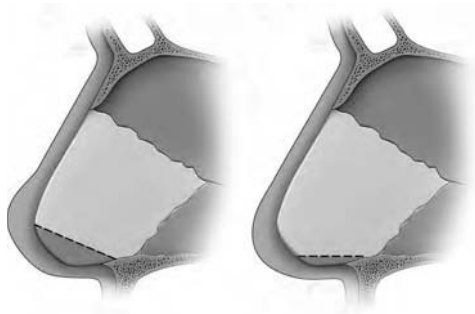


FIGURE 53 Caudal septal resection to affect tip rotation.

It is also vital to prevent a potential step-off deformity by maintaining a smooth fracture line low along the bony vault. The cephalic margin of the osteotomy should not be higher than the medial canthal ligament, as the thick nasal bones above this area increase the technical difficulty, and it is possible to cause iatrogenic injury to the lacrimal system with resultant epiphora.

A “low-to-high” osteotomy begins low at the piriform aperture and ends “high” medially on the dorsum, and is generally used to correct a small open roof deformity or to mobilize a medium-wide nasal base. The nasal bones are then medialized by a gentle greenstick fracture along predictable fracture patterns obtained based on nasal bone thickness (25). Thicker nasal bones may require a separate superior oblique osteotomy in order to mobilize them enough to be greensticked.

A “low-to-low” osteotomy starts low along the piriform aperture and continues low along the base of the bony vault to end up in a lateral position along the dorsum near the intercanthal line. It is generally considered a more powerful technique in that it results in more significant medialization of the nasal bones, and therefore is classically used when there is a large open-roof deformity or if a wide bony base requires correction. This type of osteotomy technique is frequently accompanied by a medial osteotomy in order to better mobilize the nasal bones to achieve the desired result.

Medial osteotomies are used to facilitate medial positioning of the nasal bones and are generally indicated in patients with thick nasal bones or wide bony bases in order to achieve a more predictable fracture pattern. Although medial osteotomies are frequently used in combination with lateral osteotomies, it is not necessary to use both in all cases. If both techniques are performed, however, the medial osteotomy is usually performed first as this makes it technically easier to perform the subsequent lateral osteotomy. The cant of the medial osteotomy can be oriented in a medial oblique, paramedian, or transverse direction (Fig. 56). However, regardless of the cant, the cephalic margin still should not cross the intercanthal line for the reasons stated previously. It is also important to avoid placing the medial osteotomy too far medially as it connects with the lateral osteotomy as this can cause a “rocker deformity,” where

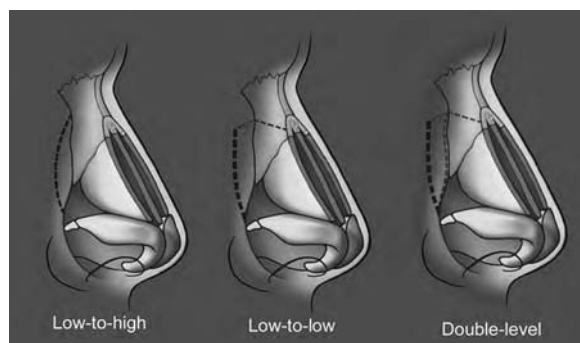


FIGURE 54 Types of osteotomies.

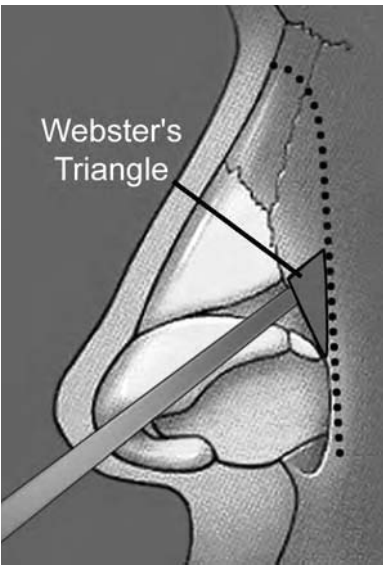


FIGURE 55 Preservation of Webster's triangle will help prevent nasal airway obstruction from internal valve collapse.

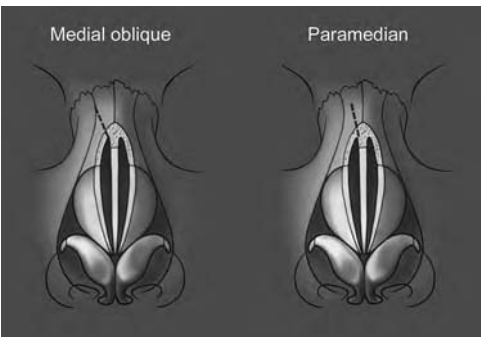


FIGURE 56 Different cants of medial osteotomies.

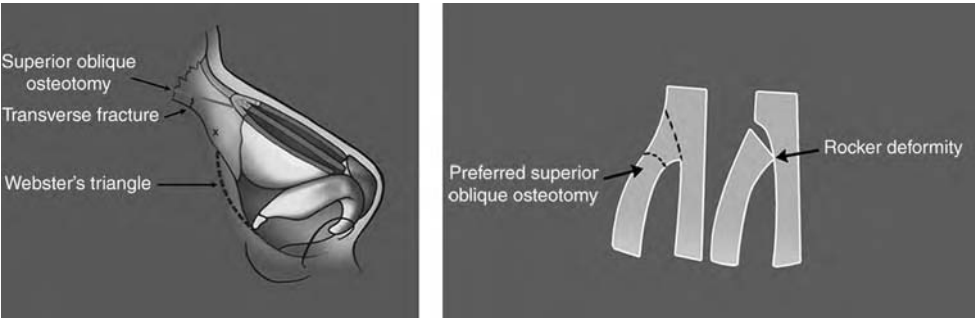


FIGURE 57 The Rocker deformity.

a widened upper dorsum results from the fractured nasal bone “kicking out.” This can be avoided by following a superior oblique angle (Fig. 57).

A double-level lateral osteotomy is indicated in cases where there is excessive lateral wall convexities that are too great to be corrected with a standard single-level lateral osteotomy or when significant lateral nasal wall asymmetries exist. The more medial of the two lateral osteotomies is first created along the nasomaxillary suture line. The more lateral of the two is then created in standard low-to-low fashion (Fig. 58).

Some of the potential complications that can occur with osteotomies (of any type) have been mentioned above. A more complete list is given next (26) (Table 5).

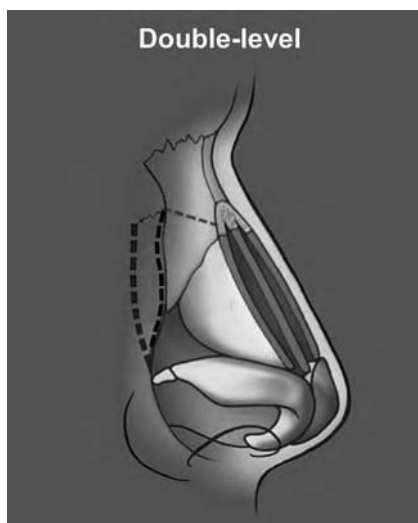


FIGURE 58 The double-level osteotomy.

Closure

At the conclusion of the procedure, after meticulous hemostasis has been obtained, the skin envelope is redraped. We may choose to place a single 5-0 Vicryl suture from the underside of the skin envelope to the underlying cartilaginous framework in an attempt to recreate a supratip break, especially if the patient has thick skin or if the patient is a female (as males usually do not have a significant supratip break).

The transculmellar incision is closed in simple interrupted fashion using 6-0 nylon suture, assuring precise reapproximation of the incision (Fig. 59). The infracartilaginous incisions are reapproximated using 5-0 chromic suture in simple interrupted fashion. Special care is taken to prevent overbiting with the suture, especially in the soft triangle area, as contour irregularities and notching may result.

The throat pack is removed and the oropharynx and stomach are carefully suctioned to help evacuate any blood which may result in postoperative nausea and vomiting. Antibiotic ointment-coated intranasal silastic splints are placed if septal work has been performed, which are secured with a transseptal 3-0 nylon suture (Fig. 60A and B). The nasal dorsum is then carefully taped and a malleable metal splint is applied over the dorsum. Finally, a drip pad is fashioned from a 2 × 2 and secured under the nose with ½ inch paper tape.

POSTOPERATIVE MANAGEMENT

All preoperative and postoperative instructions are reviewed verbally and in writing prior to as well as on the day of surgery. We routinely prescribe the following:

TABLE 5 Complications of Lateral Nasal Osteotomies

Infections	Operative trauma	Cosmetic problems
Local	Hemorrhage (hematoma, ecchymosis)	Excessive narrowing or convexity
Abscess	Nasal cyst formation	Insufficient mobilization of lateral bony walls
Cellulitis	Anosmia	Unstable bony pyramid
Granuloma	Arteriovenous fistula	Rocker formation
Systemic	Epiphora	Redundant soft tissue
Intracranial	Canalicular bleeding	Stair-step deformity
	Neuromuscular injury	Nasal bone asymmetry
	Intracranial injury	

Source: From Ref. 26.



FIGURE 59 Precise closure of the transcolumellar incision.

1. Cephalexin 500 mg PO q8h $\times$ three days
2. Methylprednisolone Dosepak (Medrol) $\times$ seven days (to minimize postoperative edema)
3. Hydrocodone/Acetaminophen 5/500 for postoperative pain q4-6h PRN
4. Normal nasal saline for postoperative nasal congestion

During the first 48–72 hours, the patient is instructed to keep the head of bed elevated at 45° and use a chilled gel eye mask (Swiss eye therapy) to help minimize postoperative swelling. The drip pad under the nose is changed as often as necessary until the drainage stops, at which time it can be discontinued. Any manipulation of the nose, including rubbing, blotting, or blowing, is discouraged for the first three weeks postoperatively. Sneezing should be done through the mouth during this time. It is imperative to keep the nasal splint dry in order to prevent premature discontinuation of the splint. The hair should be washed as in a beauty salon, with the patient leaning the head backward over the sink.

Our preference is to keep our patients on a liquid diet on the day of surgery and then advance them to a soft regular diet the following day. Any foods that require excessive lip movements, such as eating apples or corn on the cob, should be avoided for two weeks after surgery.

During the first two weeks, nasal congestion should be treated with the use of normal saline nasal spray and over-the-counter oxymetolazone nasal sprays (i.e., Afrin®). The patient is encouraged to breathe through their mouth if there is difficulty with air passage through the intranasal splints. Extreme congestion should be treated with office suctioning.

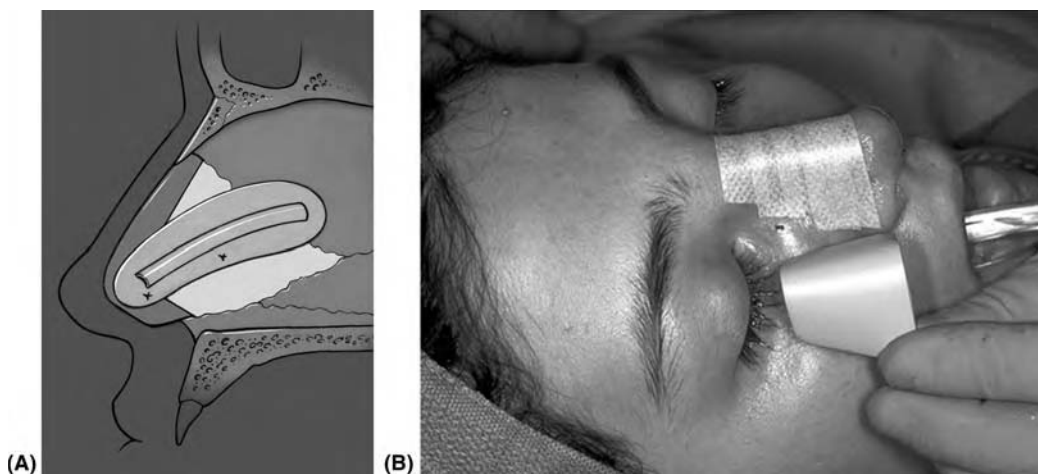


FIGURE 60 Placement of intranasal silastic (A) and external malleable (B) metal splints.

The sutures and nasal splints are removed at the initial visit on postoperative days five to seven. The nose (especially the tip) may appear swollen and turned up and the tip may feel numb, but the patient is reassured that both are expected and will resolve with time. Normal sensation usually returns within three to six months. The patient is instructed to avoid letting anything, including eyeglasses, rest on the nose for at least four weeks. During this time, glasses should be taped to the forehead. Contacts may be worn as soon as the swelling has diminished enough to allow easy insertion (usually less than five to seven days postoperatively). The patient is also instructed to avoid direct sunlight and to wear SPF 15 or greater sunscreen to prevent possible hyperpigmentation of the incision.

We restrict the patient's activity for three weeks postoperatively, after which they can gradually resume normal activity. Any contact sports or activities that may cause direct trauma to the nose are prohibited for at least four to six weeks after surgery. Although some noses look excellent within six to eight weeks, some may remain swollen for up to one year, but after three to four weeks, it will generally not be obvious to anyone but the patient.

After the first postoperative visit, we return the patient to the clinic at three and eight weeks after the operation. We continue to follow the patient at postoperative months 3, 6, and 12, and then annually thereafter.

SECONDARY RHINOPLASTY

Secondary rhinoplasty offers a unique set of challenges to the rhinoplasty surgeon. Issues such as cicatricial tissue, altered or compromised vascularity, and distorted anatomy can be major factors that alter the planning and execution of a secondary revision. Also, frequently the septal cartilage has already been harvested, which creates the need for remote cartilage harvest from locations such as the conchal bowl or rib.

In the senior author's experience, approximately one in 25 primary rhinoplasty patients requires revision. The underlying etiology that drives the need for reoperation usually includes one or a combination of the following:

1. Displaced anatomic structures
2. Undercorrection from an overconservative primary procedure
3. Overresection/overcorrection from overzealous surgery

In the lower third of the nose, the most frequent reasons for reoperation include further tip refinement or correction of tip asymmetries. In the middle third, a parrot beak or pinched supratip deformity is responsible for most revisions. In the upper third, it is excessive dorsal reduction or dorsal irregularities that require revision.

Functionally, continued nasal airway obstruction from excessive narrowing of the internal valve (without placement of spreader grafts) has been the most common reason for secondary rhinoplasty, though once we adopted the component dorsum reduction technique with preservation of the ULCs, our incidence of internal valve obstruction decreased.

Regardless of the etiology of the deformity, however, we prefer to use an external approach when performing secondary rhinoplasty as it affords excellent exposure of the underlying nasal framework, permits accurate anatomic diagnosis, and facilitates complete correction.

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19 Imaging of Soft-Tissue Defects

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INTRODUCTION

This chapter proposes a new approach to soft-tissue imaging for facial plastic surgery, including the role of imaging and computer simulation in assessing surgical cases. It explores how computer modeling and simulation have been used in plastic surgery, and includes case studies to illustrate these new technologies in practice.

Surgeons typically go through a series of steps as they plan their operations: assess the physical condition of the patient; decide what result they would like to achieve; and plan the necessary steps to achieve the desired result. The quality of information obtained during this process is the key to achieving optimum results, particularly in plastic surgery, which requires careful approximation of the final visual outcome of the procedures performed. Due to recent modern technological advances, the volume of information available to the surgeon has greatly expanded, increasing the potential to more clearly understand the issues at hand. In order to manage the increasing amount of data, surgeons may find it beneficial to consider the following three domains as they evaluate patients: physical, informational, and cognitive (Fig. 1) (1).

Physical Domain

This domain is the patient's physical state, or physical body. The main goal of plastic surgery is to take the physical state of the patient as it exists—the raw material consisting of bone, muscle, cartilage, fat, and skin—and to change it into one that is more functionally or cosmetically desirable.

For centuries, surgeons have obtained direct knowledge of the physical state of their patients in the operating room through their senses by direct sight, touch, hearing, and even smell. With the advent of X-rays in 1896, indirect information about patients' physical states became available. Even today, most of the information about patients is indirect, or not directly sensed, and are mere representations of the actual anatomy.

Although valuable, indirect information obtained through radiographic techniques has paled in comparison with what could be obtained directly until relatively recently. Improvements in indirect techniques and the combination of imaging with computer technologies have produced visual representations with unprecedented precision and breadth. With the addition of mathematical modeling to this equation, plastic surgeons will have even more sophisticated imaging techniques at their disposal, ushering in an era that may make surgical exploratory procedures obsolete some day.

Informational Domain

In surgery, information refers to the collected facts and data about a particular patient and the patient's condition, and usually includes imaging studies such as X-rays, magnetic resonance imagings (MRIs), and computed tomography (CT) scans. This information is used to translate physical data into a form that can be used to make clinical decisions.

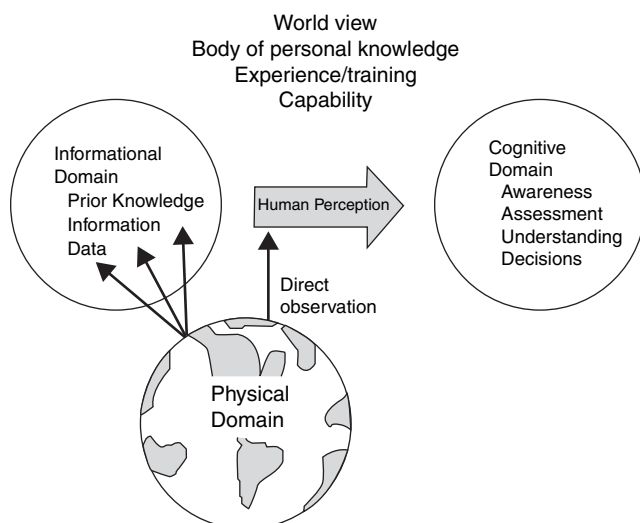


FIGURE 1 Surgeons must go through a process of data collection and assessment before action can be taken. The three domains involved in this process are the physical, informational, and cognitive. Effective data-management is key to arriving at the best decision (1). *Source:* From Ref. 1.

In addition to being improved in quality, the variety and accessibility of radiographic information have greatly increased in the past decade. The wide range of imaging techniques provides complementary data that surgeons can use to more effectively plan their surgeries. Also, the digitization of radiographic images enables clinicians to create patient-specific models to plan surgeries, collaborate with and train colleagues, and educate patients. For example, plastic surgeons can now take patient-specific information of the patient's nose, and demonstrate visually what the patient can expect from a rhinoplasty. Previously, plastic surgeons were only capable of showing photos of similar cases, requiring both surgeons and patients to merely imagine the final appearance postoperatively.

Now that radiographic data can be digitized, information can readily be shared across disciplines, between surgeons, and with patients. Radiographic data that were previously too large to transmit via the Internet can also be quickly sent due to increasing bandwidth. In addition to improved data transmission, digitization allows clinicians to transmit radiographic information to distant medical centers for review and manipulation by the leading specialists in the field. Real time collaboration through sharing of data and knowledge is now possible (2).

Cognitive Domain

Finally, surgeons must have a cognitive grasp of the information in order to make sound decisions about their surgical approaches. Due to the array of imaging techniques available, gaining understanding requires more than just collecting all the potentially available information about a patient. Rather, physicians need to be information managers who efficiently and effectively use appropriate imaging techniques from which to base their clinical decisions.

Fortunately, besides creating visual images of patients in exquisite detail, computers can aid in information management. For example, computer programs can help predict the outcome of different courses of action. Data-fusion, which superimposes computerized images onto real patients, can be used to meticulously plan where to make incisions and how to reposition bone and soft tissue. Used by the military for decades to estimate the precise location of enemy targets, this technology has only recently been applied in medicine. As in military strategy, data-fusion has the potential to revolutionize how "targets" such as soft tissue, are visualized.

TISSUE MODELING—TWO-DIMENSIONAL AND THREE-DIMENSIONAL

Using a leaf as a template, surgeons in India used forehead flaps for nasal reconstruction as early as 600 B.C. Subsequently, surgeons made templates from modeling clay by molding the

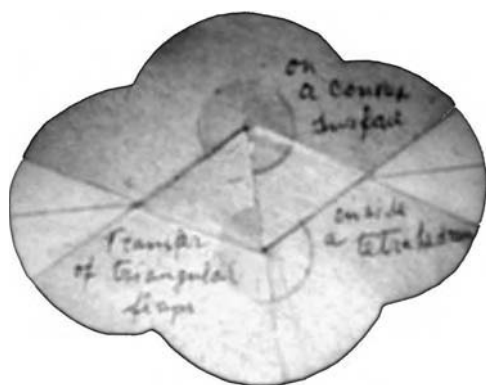


FIGURE 2 Russian surgeon Limberg cut and folded pieces of paper or cloth to approximate the three-dimensional distortion caused by tissue rearrangement *Source:* Folded paper model made by A. A. Limberg.

clay onto the body part being reconstructed, and then using the mold as a template for a flap or graft. Current modeling techniques are based on the work of Russian surgeon Limberg, who made complex templates from various materials in the first half of the 20th century (3). He cut and folded pieces of paper or cloth to approximate the three-dimensional distortion caused by tissue rearrangement (Fig. 2). Applying basic geometry principles, Limberg created these paper and cloth models to envision the consequences of geometric manipulation on living tissue. Cloth-folding techniques can still be used as effective templates for nose flaps, as was done for a patient who had a forehead flap reconstruction in the year 2000 (Fig. 3). Despite their usefulness in these procedures, paper and cloth templates are still limited in their ability to predict actual results because they do not possess the exact properties of skin and underlying tissues such as elasticity and wound-healing responses or predict changes over time.

The introduction of the computer midway through the 20th century provided a tool with the potential to model the complexity of real tissues. However, early computer programs were incapable of solving the large sets of equations to represent skin and soft tissue. Even if computer programs were available to accomplish such a feat, mathematical models of the mechanical behavior of materials were too primitive to realistically represent human tissues. By the end of



FIGURE 3 Cloth-folding techniques can still be used as effective templates for nose flaps, as was done for this patient who had a forehead flap reconstruction in the year 2000 *Source:* From Ref. 26.

the 20th century, however, computer animation techniques were created to simulate the behavior of human skin, muscle, and bones, by which time computers could handle such large amount of data. Using interactive graphic interfaces, surgeons could plan for, and simulate the outcome of surgical procedures with two- and three-dimensional data. The most advanced interface is virtual reality (VR). In one example of VR, surgeons wear specialized helmets and gloves so that they can see and feel for example, a reconstructed nose.

Modern computer programs use two- and three-dimensional data to display the results of surgery. Plastic surgeons routinely use two-dimensional displays to predict the results of surgeries such as rhinoplasties, mid-face advancements, and mandibular osteotomies (4). Clinicians can then digitally retouch or paint these images. Since these graphic images do not incorporate the physical properties of tissues, however, final images rely on the surgeon's skill in predicting the outcome, and retouching the final images.

Although available, three-dimensional displays are not yet considered the standard of care, and the evidence about the effectiveness of such images is still sparse. However, since it incorporates depth into its images, three-dimensional modeling may be the next phase in the development of imaging techniques. Three-dimensional patient-specific data obtained from radiology studies such as CT and MRI scans are formatted by computer graphic rendering techniques into visual three-dimensional objects. Surgical outcomes can also be simulated, and have been based on segmental cuts of three-dimensional data. These simulations have been useful in bone surgery, such as craniofacial surgery (5,6), since the modeled tissue is rigid. This technique has also been useful in soft-tissue modeling because it helps to visualize soft tissue in relationship to bone, as was used in a patient with a subcutaneous lesion, which will be discussed below (Fig. 4).

Patient-specific models for human organs can be created using data from CT or MRI scans. One method takes thin slice spiral CT or MRI data on CD and processes them into patient-specific interactive models that are viewed with treatment planning software. Used by the U.S. Food and Drug Administration to track outcomes, this system is used widely for abdominal aortic aneurysm stent implants and kidney transplants (7). Several examples of this technique are illustrated next (Figs. 4–6).

The first example is a three-dimensional model of a patient with a subcutaneous lesion on the forehead (Fig. 5). Unlike a static two-dimensional image, this interactive three-dimensional image conveys the three-dimensional extent of the lesion. The lesion can be viewed with the skin intact or removed, while simultaneously viewing the original MRI slice data (Fig. 4).

In the next example, three-dimensional modeling was used to help construct and replace an ear for a patient with a congenital absence of an ear, or microtia. The three-dimensional model of both the skin and the cartilage of the patient's intact left ear was first created using CT slice data. This model was then mirrored to create a model for the new right ear. Physical models

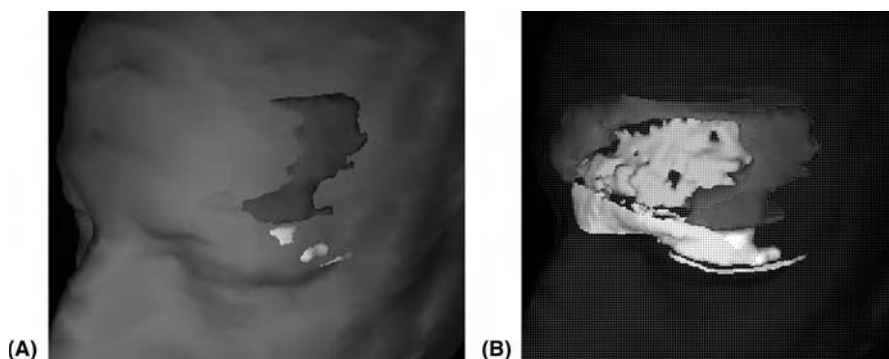


FIGURE 4 Patient-specific, three-dimensional models can be created using computer-based imaging technology to view subcutaneous lesions on the forehead. The same model can be viewed with the skin intact (A) or transparent (B). Source: courtesy of Medical Media Systems Inc.

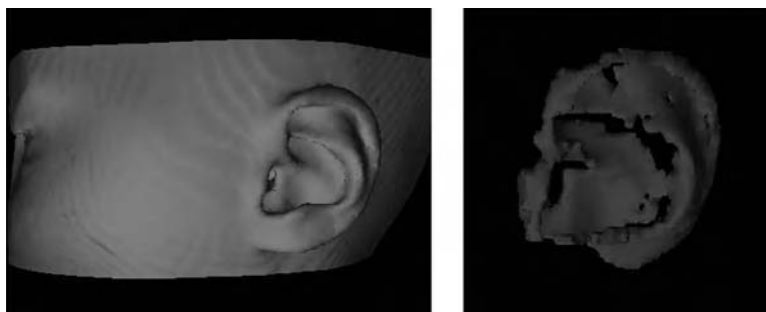


FIGURE 5 A three-dimensional model of the skin and cartilage of a patient's intact ear can be used to create a model for replacing the opposite ear in the case of congenital microtia. *Source:* courtesy of Medical Media Systems Inc.

of the new ear and cartilage were created using a computer-aided extruder device at the Thayer School of Engineering. Previous radiographic techniques could image external structures, but were incapable of imaging underlying tissues such as cartilage.

SIMULATION

Simulation of Surgical Procedures

In addition to modeling, the computer can function as an expert system that assists surgeons in developing treatment plans for their patients. An early example of an expert system guided clinicians through a series of predetermined case histories and images, and gave them a menu of procedural options. The program then produced potential outcomes based on the options that were chosen. Constantian was the first surgeon to develop a rhinoplasty simulator that functioned as an expert system (8). Similar to flight simulation, surgical simulators such as Constantian's trained users to perform complex tasks in an interactive computer environment (9).

As with tissue modeling, surgical simulation has progressed from two-dimensional, such as photographs and radiographs, to three-dimensional VR. Today, volumetric data obtained from computer-aided scans are capable of creating three-dimensional images. These images are particularly helpful in planning complex operations, since they allow surgeons to experiment with a variety of reconstructive techniques prior to going into the operating room.

Simulation of Tissues

Although three-dimensional technologies provide exceptional opportunities to simulate actual surgeries, they are still imperfect because they lack data that reflect tissue properties and do not include pathologic tissue states. Thus, tissue simulations are based on the action of normal

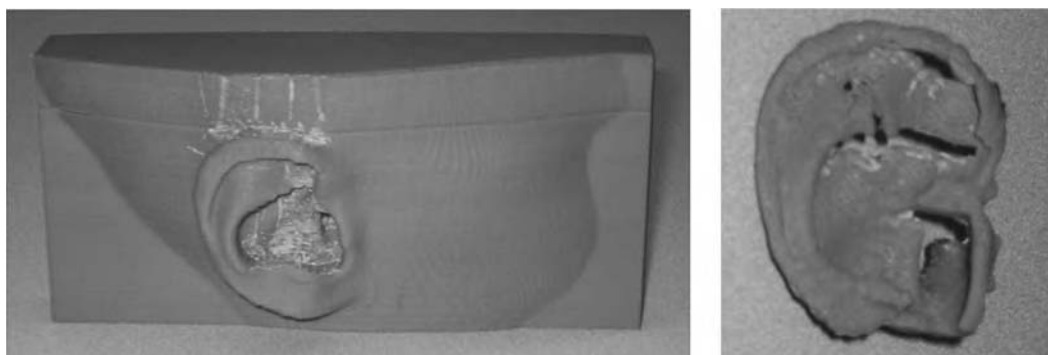


FIGURE 6 Physical models of the skin and cartilage of the missing ear were created out of plastic using a computer-aided extruder *Source:* From Ref. 27.

tissues, and do not reflect that of tissues that are abnormal, which is often the case in patients requiring plastic surgery.

Mathematical modeling has been considered in plastic surgery for at decades by surgeons such as Limberg, and is thought to be the missing link in codifying the behavior of actual tissues. Not surprisingly, creating these mathematical models has proven to be difficult, and tissue simulation remains an ongoing area of research. However, research in tissue behavior has progressed to the point of providing clinically applicable information that could soon be used in the clinic or operating room.

Background Research in Tissue Simulation

For computer simulation to be effective, all tissues within a given field must be accounted for so that the eventual simulation reflects the actual behavior of the tissue. Three-dimensional patient data from CT scans, MRI, and positron emission tomography are encoded volumetrically, that is each point in space is defined by an absolute reference frame independent of the patient, and the material is encoded at each of these points. There is no common reference point within each set of data or between sets. These data are not immediately amenable to modeling because there is no information as to how each piece of material connects to other pieces of the material, or how they might behave. Researchers have attempted to address the problem by using a system called finite element mesh (FEM), which approximates the properties of skin, muscle, and bone.

FEM divides a material with complex geometry such as skin into regions, or elements, that taken together, approximate the behavior of the entire material. Each element is defined by the boundaries it shares with other elements. A matrix with the material properties of the elements predicts each element's distortion, but it still shares the same borders with the other elements. There are several mathematical algorithms for the construction of FEMs based on data in volume data sets (10).

FEM has been used to simulate the behavior of limbs, the biomechanics and anatomy of which are simpler to recreate than the complex musculature and joints of the head and neck. One of the earliest surgical simulators used a computer simulation of the lower extremity musculotendinous system to analyze tendon transfer operations (11). Using a computer-generated model of the hip joint with muscle and tendon actuators, the outcome of hip arthroplastic surgeries were predicted. By simulating 41 muscle-tendon complexes, the maximum force generated by leg abduction, adduction, flexion, and extension in relation to the position of the hip joint itself was found (12).

Using this model, the effect of hip prosthesis position on individual muscle groups can be predicted. Expanding the model to include major muscles of the entire lower extremity, Delp and Zajac were able to make predictions concerning the effect of tendon lengthening and transfers on muscle strength (13). For example, they found that the length of certain muscles determine their force. Tendon transfers are already performed on patients with gait or posture abnormalities due to stroke or cerebral palsy. In the future, this technology can be applied to cranio-facial applications such as reconstruction of the jaw and associated muscles.

Chen and Zeltzer (14) combined realistic computer animation with valid biomechanical simulation of muscle. Taking human animation beyond simulating surface geometry of skin, the researchers detailed the modeling of individual muscles. They constructed a polyhedral model of the gastrocnemius by using reconstructed three-dimensional images from CT, MRI data, and a three-dimensional modeling program synthesized by FEM. By developing a model that could simulate actual muscle force and visualize the dynamics of muscle contraction, Chen and Zeltzer created an animated character that changes shape accurately and realistically.

Early Applications to Surgical Training

Satava has created a "virtual abdomen" to teach medical students specific anatomic details of abdominal organs, and to instruct surgical residents in surgical techniques and operative procedures (15). This computer model allows the viewer to see the anatomy from outside of the organs, as in an open laparotomy, but also from the inside, as with endoscopic procedures. Trainees can use virtual laparoscopic tools to perform simulated minimally invasive surgery such as tumor removal.

Tissue Simulation in Plastic Surgery

Studies using FEM and the behavior of muscles and tendons laid the foundation for improving imaging techniques in plastic surgery. For example, Larabee analyzed flap advancements by comparing a two-dimensional FEM simulation of human skin to pig skin (16). In addition, Kawabata analyzed the effect of various Z-plasty parameters with a two-dimensional FEM (17). Likewise, Motoyoshi used an FEM model of facial soft tissue to predict the outcome of orthognathic surgery (18), while Lee used an FEM with overlying detail similar to computer-aided plastic surgery (CAPS) to generate computer-synthesized facial expression (19).

The face is probably the most difficult area of the human body to simulate. Simulating the structure and movements of the face requires replicating multiple elements of facial expression such as its fluidity, individuality, and intricate musculature. Early efforts at key frame animation of the face were satisfactory for two-dimensional modeling. However, the length of time required to specify the large number of key frames for three-dimensional simulation, proved to be prohibitive (20).

In the early 1980s, Platt and Badler simulated the human face by using a three-layered model including skin, muscle, and bone. In their model, skin is represented by a set of points with three-dimensional coordinates, while bone is represented as a rigid surface below the skin. The muscle is a group of muscle-fiber points connected by elastic arcs to the overlying skin and underlying bone. Points on the skin are connected also to neighboring points through arcs. By integrating the network of points, one can demonstrate how the application of force or tension on one section of the model will affect more distant areas of the same surface (21).

COMPUTER-AIDED PLASTIC SURGERY: PRE-OP PLANNING

Computer-aided plastic surgery, or CAPS, allows plastic surgeons to plan, analyze, and visualize the soft tissue of the face. Pieper had developed a detailed model of the face using reconstructed images from CT and MRI scans of the patient (22). It is a prototype computer program that a surgeon could use as a sketch pad to predict and compare the outcome of facial plastic procedures on a patient-specific physical model. One can select incision placement, move tissue, and suture. The CAPS program uses an FEM to simulate plastic surgery by removing certain elements and then redefining the remaining elements as sharing their (formerly separate) borders, just as a surgeon excises tissue and defines new shared edges with sutures. When the computer calculates the distorting forces and applies this to the patient-specific model, one can visualize the consequences of the surgery.

Xia et al. (23) created a similar three-dimensional virtual-reality surgical-planning workbench (three-dimensional VRSP) more recently that also combines CT reconstruction with



FIGURE 7 The computer-aided plastic surgery program can create videos predicting the effect of tissue removal from multiple angles for a specific patient based on a Finite Element Mesh model *Source:* From Ref. 28.

color-photography to create a three-dimensional color facial soft-tissue model. Virtual surgical planning and simulation can be performed as well as preoperative prediction of soft-tissue change (23).

Although one would like to create an exact model of human facial tissues, this still remains to be done. The present model is of a homogeneous layer of uniform thickness, a simplification of the actual human face with varying thickness of facial soft tissue. This is analogous to predicting the outcome of facial surgery by using a detailed facial model made of uniformly thick foam rubber.

DATAFUSION: PERIOPERATIVE

VR applications were initially created for preoperative use. However, new developments now allow the use of VR perioperatively in a technology called datafusion. Datafusion blends virtual patients with real patients as a navigational aid in surgery. Eventually, multiple professionals will be able to share a virtual environment that incorporates shared decision making for rehearsed or actual surgeries.

The major applications of VR in surgery can be divided into three areas: virtual humans for training, the fusion of virtual humans with real humans for performing surgery, and virtual telemedicine shared decision environments for training of multiple players. The applications pertaining to the realization of VR in medicine can be categorized into two areas: generic models and patient specific models.

Generic models of organs or of the human body are built on nonspecific data or normal data. These model applications allow the user to interact with the model and visualize the results of his or her actions. The physiology and pathophysiology will also be demonstrated. Therefore, there will be a distinction between static (three-dimensional) and/or interactive programs (four-dimensional, including time). Patient-specific models are based on data from an actual patient. This can begin with a generic model, which is then modified to build a patient specific model that incorporates pertinent data about the specific patient.

The user interface and interactive capabilities of a program distinguish between passive and active applications. Another aspect of these applications is the ability to integrate real-time patients specific data into the virtual environment. Data-fusion addresses the capability of an application to use real-time data from the patient during a procedure, combining it with a specific model and superimposed to give the surgeon "quasi-X-Ray-Vision" (24). Real-time image data for use with data fusion programs is collected using CT, MRI, or three-dimensional ultrasound, photography, and laser scanning.

DISCUSSIONS AND FUTURE PREDICTIONS

Modeling and surgical simulation techniques have progressed from leaf templates in 600 B.C. to sophisticated VR programs today (Fig. 8). Nevertheless, the goal of having precise imaging techniques available throughout the process of surgical patient care—from the preoperative workup, through the surgery, and through the postoperative period—remains to be seen. Fortunately, research has targeted the application of various imaging technologies in all three periods of surgical care, and has shown some promising breakthroughs. However, many available advancements have not yet been applied to plastic surgery, suggesting that there is still plenty of room for clinical research in imaging techniques.

In an idyllic preoperative world, plastic surgeons will have fully interactive patient-specific models on which to predict outcomes based on various procedures, and on which to practice surgical procedures. Thus far, imaging technology is the most advanced for the preoperative period. For example, commercially available systems now allow three-dimensional data to be converted into a view of the patient's skeleton that incorporates the overlying muscle and skin. In the near future, head and neck surgeons will be able to use these programs to plan complex congenital, traumatic, and tumor resections.

Despite these advancements, however, precisely predicting surgical outcomes for specific patients has yet to be possible. Communication advances hold the promise that some day, multiple physicians from around the world will be able to simultaneously consult on a case

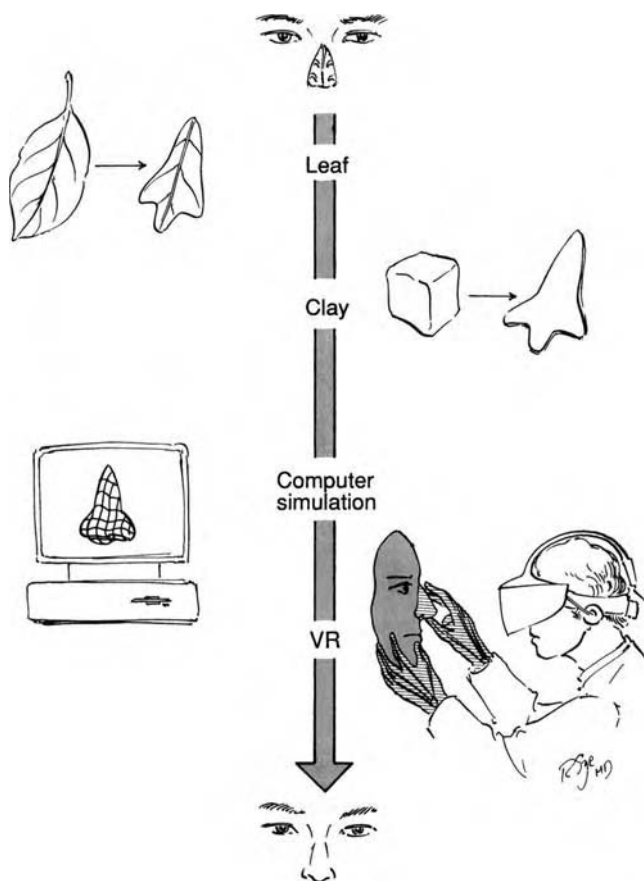


FIGURE 8 The history of nasal-reconstruction planning begins with a leaf template, then progresses through clay modeling and computer modeling. In the future, surgeons will be able to plan procedures in virtual reality. *Source:* From Ref. 29.

preoperatively. In addition, by applying VR and robotics technologies, surgeons may in the future be able to rehearse entire surgeries before stepping into the operating room.

Potential preoperative applications of new technologies can be illustrated by using the nose as our test case. For example, a future simulator of rhinoplasty surgery could be a digital representation of the complex multitissue anatomy of the nose that simulates the airflow of the reconstructed nose, and the scar contraction of the nose over time. The simulation could even incorporate the artificial intelligence of Constantian's simulator, and provide critiques for specific operative maneuvers. Behaving as a "Performance Machine", these systems could incorporate stealth data-fusion systems, and intuitive robots perioperatively (25).

Through VR and intuitive robots, surgeons may one day be able to conduct surgeries from a long distance for patients who would not have had access to the surgery otherwise. Furthermore, these technologies may provide training for surgeons in remote areas as they observe or participate in them.

Compared to the preoperative period, the application of new technologies to improve postoperative care is still in its infancy. Advanced tools such as three-dimensional imaging that have proven to be useful during the preoperative period will probably also be valuable postoperatively. In addition, technologies in facial recognition, or face mapping, may become a valuable tool to assess the effectiveness of a surgery postoperatively. Face mapping, which is of obvious interest to the military and other government security agencies, has the potential to quantify how closely the surgical results matched the predicted outcomes. Moreover, such data would help to more accurately measure the success of various procedures, perhaps even driving changes in preoperative assessment and planning, and operative techniques.

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20 | Managing the Cleft Nasal Deformity: Controversies in Correction

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INTRODUCTION

The earliest comprehensive anatomical descriptions of the cleft nasal deformity belong to Huffman and Lierle (1) and were presented at a time when attention to the cleft nasal deformity was essentially limited to alar base repositioning. Dissection of the nasal complex itself was avoided because of concerns regarding growth disturbances. However, long-term work presented by McComb (2,3), Salyer (4), Boo-Chai (5), and Ortiz-Monestario (6) suggested that concerns about growth inhibition were overstated and that improved nasal form and symmetry were possible with primary cleft nasal repair. The following discussion describes the anatomical deformity of the unilateral and bilateral cleft nasal deformities and their management.

UNILATERAL CLEFT NASAL DEFORMITY

The unilateral cleft nasal deformity is characterized by (i) deviation of the nasal tip and caudal septum toward the noncleft side, (ii) deviation of the columellar base toward the noncleft side, while the (iii) cleft-side septum obstructs the airway. (iv) There is an obtuse angle between the medial and lateral crus on the cleft side. (v) The cleft side alar cartilage has a depressed dome, and (vi) a vestibular web is present in the cleft-side nostril. (vii) Cartilage on the cleft side is smaller, with the lateral crus caudally displaced, and the ala buckling inward. There is an (viii) absent alar-facial groove on the cleft side, (ix) the maxilla on the cleft side is hypoplastic; there is a (x) widened nostril floor and (xi) a retrodisplaced medial crus on the cleft side (Fig. 1A and B) (7,8).

NASOALVEOLAR MOLDING

Early work to mold the cleft nasal deformity was done by Matsua et al., who reasoned that, just as auricular cartilage is pliable (9) for the first few weeks after birth, alar cartilage has the same early pliability (10). Furthermore, because cleft lip repair often occurs at three months of age, the window of alar pliability is missed. By this time, the cleft side alar cartilage has stiffened into a deformed and difficult-to-correct state. These authors compared a group of patients whose cleft lips were repaired between two and seven days-of-life, with simultaneous nonsurgical correction of the cleft nasal deformity, to a group of infants who underwent standard lip repair at three months of life. At 12-month follow-up, nasal symmetry was judged superior in the group of patients who underwent stenting of the nasal deformity. Importantly, the nasal stents were placed bilaterally, with the desired effect being overcorrection of the cleft-side nare (11). Others have used nasal stents for at least six months (12). At six-year follow-up after nonsurgical correction of the nasal defect there was significant increase in columellar length, improved nasal symmetry, without alar luxation (13).

Nasoalveolar molding (NAM), a technique that adds a nasal stent to the labial vestibular flange of an intraoral molding plate (Fig. 2A), is held in place with surgical tape and elastics that

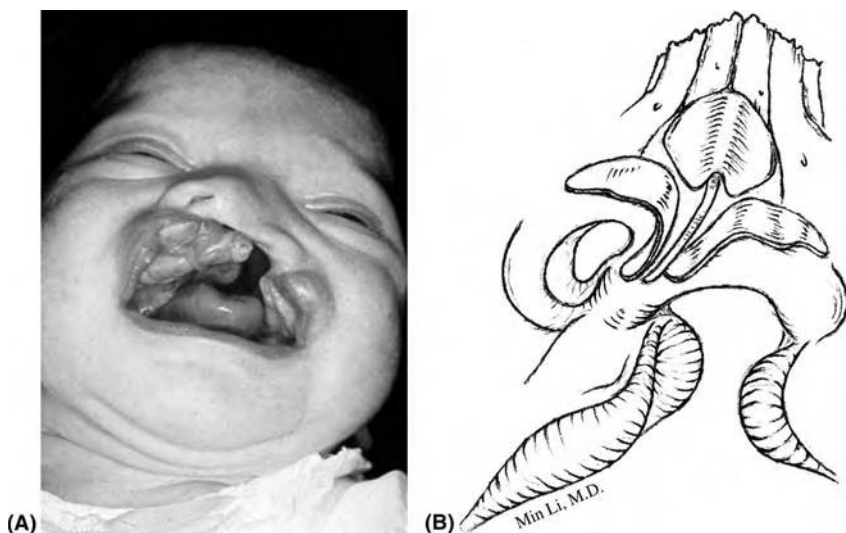


FIGURE 1 (A) An infant with unilateral cleft nasal deformity. (B) Illustration of a unilateral cleft nasal deformity, showing deviation of the nasal tip, caudal septum, and columellar base toward the noncleft side; the cleft-side findings also include depression of the lower lateral alar cartilage with a depressed dome; the lateral crus is caudally displaced with the ala buckling inward; there is retrodisplacement of the medial crus, a widened nostril floor and an absent alar-facial groove.

extend onto the cheeks (Fig. 2B). The combined effect of NAM is to bring the nasal tip forward, and to lengthen the columella by pressing against the nasolabial fold, using tissue expansion principles. Simultaneously, the domes of the lower lateral cartilages are brought toward the midline and the intranasal lining is expanded (14). The nasal stent attached to the alveolar molding plate is adjusted weekly to achieve nasal, as well as alveolar symmetry, and to improve nasal tip projection (15–17). Unilateral NAM is completed within three months, while bilateral molding is completed in five months (Fig. 2C and D) (17). In addition to improving short-term outcomes, NAM improves long-term nasal symmetry (18). Proponents of NAM suggest that the traditional need to lengthen the columella as a second procedure in bilateral clefts is eliminated.

PRIMARY UNILATERAL CLEFT NASAL REPAIR

Early proponents of simultaneous repair of the cleft lip and nasal deformity were working at a time when most practitioners used minimal dissection of the infant nose. Brown and McDowell, using a buccal fornix incision, undermined between the mucosal lining and skin of the nostril to a point across the midline, which allowed complete rotation of the cleft-side nostril into position (without “corrugation” of the lining). Nostril shape was modified by the placement of mattress sutures to hold nasal mucosa into its new relationship with nasal skin (19).

Another early advocate of primary nasal repair, William Berkley, obtained access to the cleft-side alar cartilage with a midline vertical columella-nasal-tip incision. This incision allowed bilateral mobilization of skin and subcutaneous tissue from the lower lateral cartilages; horizontal mattress sutures were placed between the two cartilages in order to redefine the nasal tip (20). Berkley’s improved results were the impetus for Millard to perform earlier cleft nasal repair (21). Millard, unhappy with nasal asymmetry following primary cleft lip repair, began using para-marginal and intercartilaginous incisions (trying to avoid the nasal tip incision favored by Berkley). He suggested an alar-cartilage lift, involving a rim incision that allowed the alar cartilage to be freed from overlying skin and inner nasal lining. This procedure was performed at 18 months of age (21). By the 1980s, Millard began advocating primary nasal correction simultaneous to lip repair (22). He made a marginal incision, freeing the cleft-side

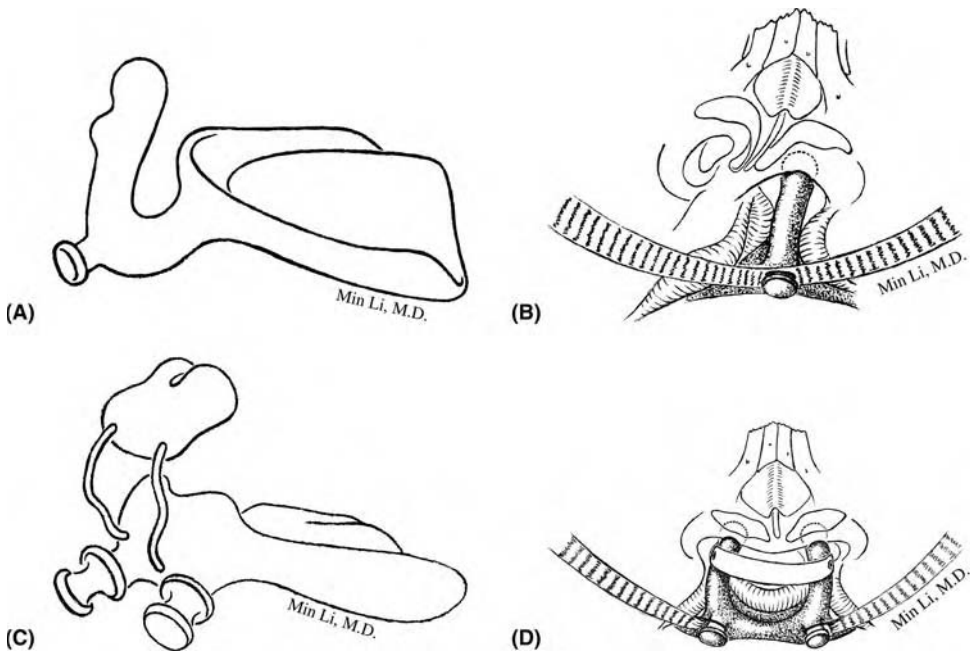


FIGURE 2 (A) Unilateral NAM plate with a nasal stent extension from the intraoral molding plate. (B) The appliance in position secured onto the cheeks. The NAM plate is adjusted as needed over a three-month period to improve nasal symmetry and nasal tip projection. (C) Bilateral NAM plate with two stents extending from the intraoral molding plate. (D) The appliance in position secured onto the cheeks. The nasal stents elevate the nasal dome; an acrylic band presses against the lip-columellar junction, stretching the tissue of the columella. *Abbreviation:* NAM, nasoalveolar molding.

alar cartilage and positioning it symmetrically with the normal side. In 1998, Millard presented 10-year follow-up, suggesting improved results using this technique (23).

Two early systematic proponents of primary cleft nasal repair were McComb and Salyer (4,24). McComb observed that the entire cleft-side half of the nose was longer and that nostril lining on the cleft side from side to side was shorter. The cleft nose, including the anterior septum and nasal pyramid, like a pendulum, canted away from the cleft side. McComb recommended shortening the cleft-side of the nose with wide undermining of skin from nasion to nostril margin. Once the skin was free, a mattress suture with bolster was used to lift the intercrural angle of the alar arch, pulling this toward the nasion. This maneuver placed the alar cartilage and nostril lining into correct position (24). In 1984, McComb published a 10-year review of this technique, suggesting that there was no evidence of nasal growth interruption; changes made in the alar cartilages and nasal tip were maintained (2) and that the vertical shortening of the nose by alar lift was preserved into adult life (25).

In 1986, Salyer reported on 15-year follow-up of patients who had undergone primary cleft rhinoplasty starting in 1970 (4). These patients showed no evidence of nasal growth inhibition. To approach the lower lateral cartilage, Salyer uses the c-flap incision of the lip repair; the medial crura are dissected apart (Fig. 3B); the dissection then proceeds over the alar dome and the skin is undermined over both lower lateral cartilages. The skin of the columella is dissected from the medial crura (Fig. 3C). The stated goal is to free the entire skin from both lower lateral cartilages. Following total undermining, the cleft-side alar base is placed in symmetric position to the noncleft alar base. With the lower lateral cartilage in a correct position, the skin and lining were redraped to create a symmetrical ala, nasal tip, and alar base. Sutures are placed to hold the cartilage in a new position (Fig. 3D and E). Stents help mold the nasal tip and ala into the desired shape. The stents are removed in 7 to 10 days. Salyer reports that 80% of patients who undergo primary cleft nasal repair do not require cleft nasal revision (4).

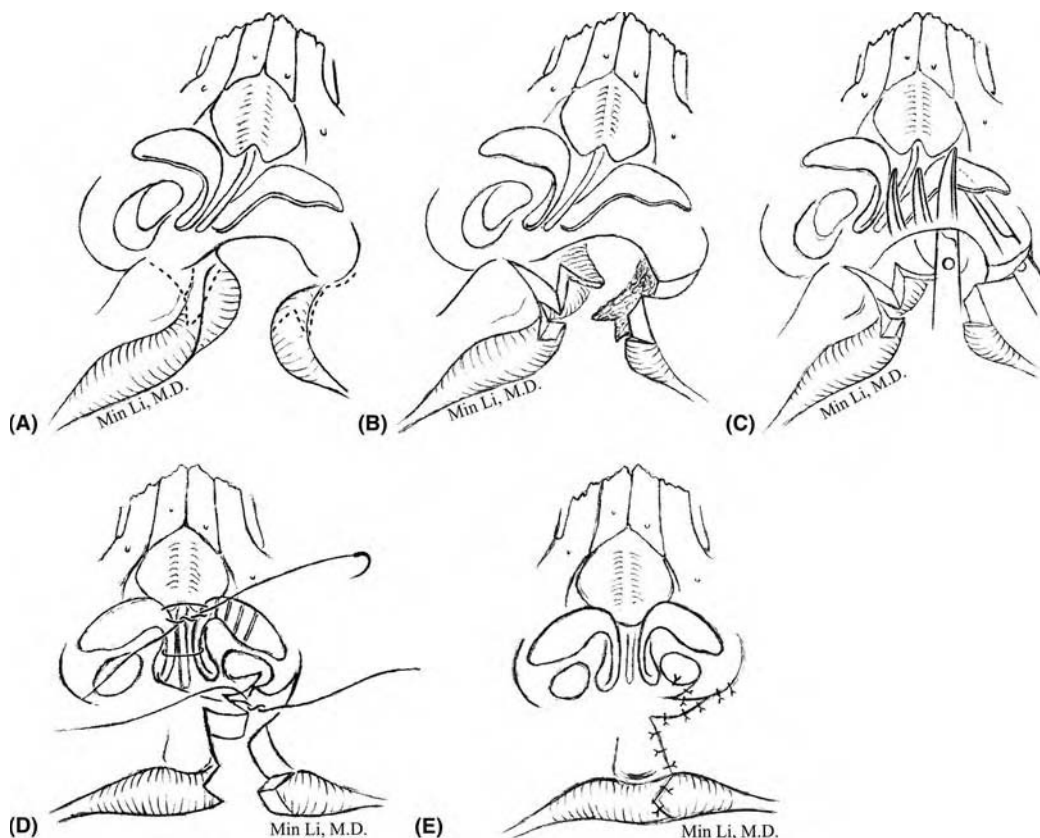


FIGURE 3 (A) An unilateral cleft nasal deformity. (B) Incisions used for lip repair and access to the nasal deformity. (C) Access to the lower lateral cartilage is gained through the c-flap and from the lateral alar incisions. Tenotomy scissors separate the skin envelope from the lower lateral cartilage on the side of the cleft. Laterally, Salyer also separates the nasal lining from the underside of the lower lateral cartilage. Medially the nasal lining is not dissected. (D) A combination of interdomal sutures or bolsters (not shown) is used to maintain the new relationship of the cleft-side lower lateral cartilage to skin and nasal lining. (E) Final closure of the lip incisions, with the cleft-side lower lateral cartilage in its new, symmetrical position vis-à-vis the noncleft lower lateral cartilage (44).

SECONDARY REPAIR OF THE UNILATERAL CLEFT NASAL DEFORMITY

For those surgeons who believe that the infant nasal cartilage is too delicate to manipulate early, simple repositioning of the alar base at the time of primary lip repair is performed. Without manipulation of the lower lateral cartilage at primary repair, a cleft nasal revision is required in a majority of patients. This may be done at four to five years of age prior to the child's entry into school (26). Others have suggested that optimal timing is between six and nine years of age (27). The surgical technique for secondary cleft rhinoplasty can use either a closed or open approach; the closed approach, using lip incisions or rim and infracartilaginous nasal vestibular incisions is preferred by most surgeons.

Definitive open rhinoplasty is performed between the ages of 16 and 18 through an open approach after maxillary and nasal growth are complete (26). There are data, however, suggesting that nasal growth is complete at 11 to 12 years of age in girls, and 13 to 14 years of age in boys (28), leading some authors to suggest that definitive rhinoplasty may be performed at a younger age. Maturity of the child, however, needs to be taken into account when making this decision (29). The final definitive rhinoplasty involves management of nasal obstruction, including nasal septal correction and submucous resection of enlarged inferior turbinates. Osteotomies and dorsal nasal rasping, tip revisions and onlay grafting may all be required singly or in combination (27).

Outcomes

In patients who have undergone NAM, improved, retained nasal symmetry has been reported. However, because NAM is a relatively new technique, long-term follow-up is lacking, but anticipated. Cussons et al. reported on a comparison between a group of patients with unilateral cleft lip who underwent radical correction of the cleft nasal deformity at the time of primary lip repair, and a second group who only underwent lip repair, and in whom nasal repair was to be delayed until the teenage years. Not surprisingly, the rankings obtained showed improved upper nasal perimeter, nostril outline, and overall appearance of the nose in patients who underwent primary cleft nasal repair at the same time as the initial lip repair (30). Our opinion is that the best results obtained in any child with a unilateral cleft lip and nasal deformity must address the nasal deformity at the primary setting, but must be tailored to improve the child's appearance as he/she matures (Fig. 4A–E).

BILATERAL CLEFT NASAL DEFORMITY

The nasal deformities in patients with bilateral cleft lip are similar to those of the unilateral cleft nasal deformity, but are present bilaterally. The deformities include a (i) shortened columella, (ii) a depressed, broad nasal tip, and (iii) flattened nasal alae that are S-shaped. (iv) The alar bases are laterally, inferiorly, and posteriorly displaced, with the (v) nostrils oriented horizontally. (vi) The lower lateral cartilages have short medial crura that are separated at the tip. (vii) The lateral crura are elongated and flat and (viii) the nasal floor is absent. (ix) The columella, caudal septum, and anterior nasal spine are inferiorly displaced in relation to the alar bases. (x) The nasal tip and nostrils are asymmetric (Fig. 5A and B) (8).

PRIMARY BILATERAL CLEFT NASAL REPAIR

Repair of the bilateral cleft nasal deformity has lagged somewhat behind the unilateral cleft nasal deformity. In 1975, McComb recommended primary elevation of a fork flap, taken from the edges of the prolabium, for columellar elongation (31); this procedure was performed at six weeks of age. At a second stage, when the child was three months of age, McComb performed a primary rhinoplasty (with lip repair) that involved lifting the alar cartilages to correct their caudal displacement. At 10-year follow-up, McComb reported minimal residual nostril deformity and a decreased need for revisional surgery (3). However, at 15-year follow-up, McComb became disillusioned with nostril sizes that were too large, a nasal tip that was too broad and a nasal base with downward drift (32). His revised recommendation utilized an external “flying bird” incision on the nasal tip, exposing the separated alar domes; the domes were sutured to each other, and the nasal vestibule closed to take tension off the nasal tip; a lip adhesion was performed simultaneously (32). In the second stage, definitive lip repair was accomplished. Follow-up at four years showed good columellar length (33). Other authors, including Broadbent and Wolff, have described medial advancement of the alar domes combined with tissue excision between the medial crura of the lower lateral cartilages at the time of primary lip repair (34). These authors were among the first to recognize that there was sufficient tissue in the area of the domes to correct the flat nasal tip (34,35).

Driven by social and economic factors in Malaysia, Trott (36,37) began using an open rhinoplasty approach popularized by Gunter (38) for access to the dislocated alar cartilages for a single-stage nasolabial repair. The dislocated lower lateral cartilages are sutured to each other at the level of the alar domes; sutures were used to position subcutaneous fibrofatty tissue over the alar domes to provide adequate fullness at the nasal tip (36,37). Cutting et al. manage the bilateral cleft nasal deformity in a coordinated fashion with NAM, which lengthens the columella and expands the nasal vestibular lining; at the time of primary lip repair, a retrograde approach is used during which the prolabial flap and columella are lifted over the nasal dorsum. This allows exposure of the medial aspect of the lower lateral cartilages, enabling dissection of tissues between the tip cartilages and medial suturing of the domes (39).

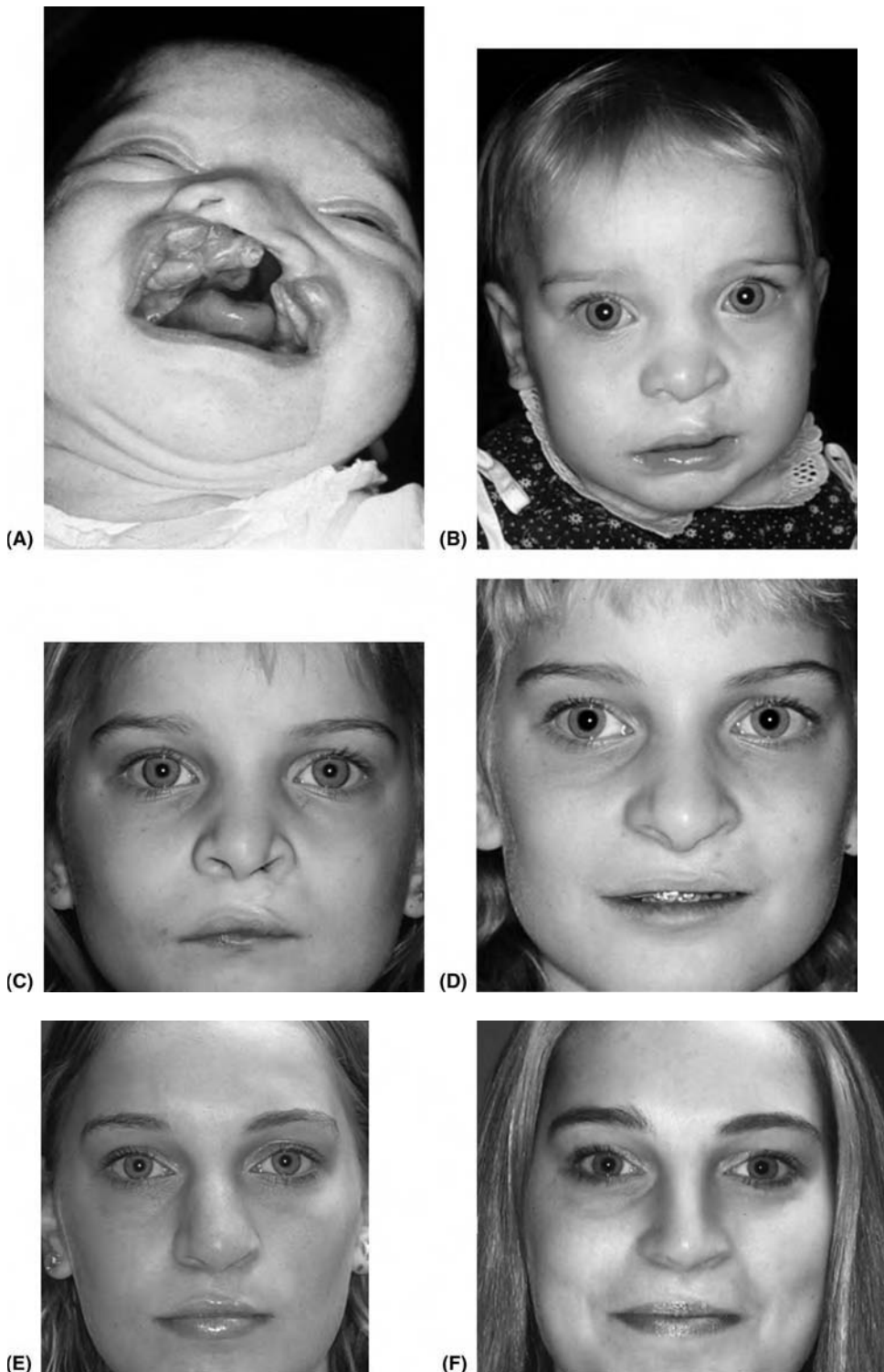


FIGURE 4 (A) An infant with a left unilateral cleft lip and nasal deformity. (B) Following primary lip and nasal revision. (C) The patient as an eight-year-old following secondary lip and nasal revisions. (D) The patient as a 10-year-old. (E) At 16 years of age, prior to definitive rhinoplasty. (F) At 19 years of age, following definitive rhinoplasty.

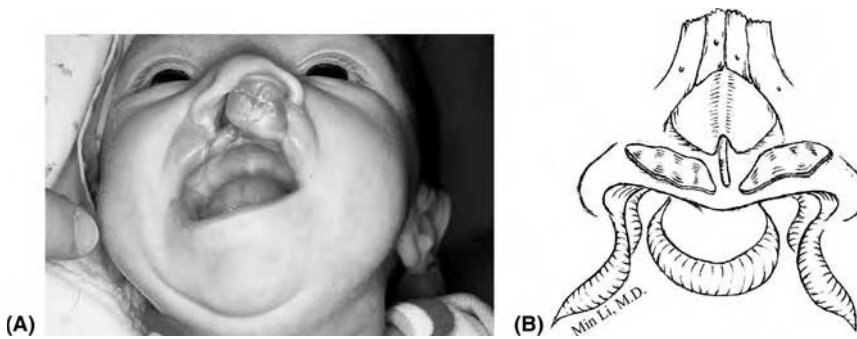


FIGURE 5 (A) An infant with bilateral cleft nasal deformity. (B) Illustration of a bilateral cleft nasal deformity, showing a shortened columella, depressed, broad nasal tip, and flattened nasal alae that are S-shaped. The alar bases are laterally, inferiorly, and posteriorly displaced, with the nostrils oriented horizontally. The lower lateral cartilages have short medial crura that are separated at the tip. The lateral crura are elongated and flat, and the nasal floor is absent. The columella, caudal septum, and anterior nasal spine are inferiorly displaced in relation to the alar bases.

Mulliken has advocated primary repair of the bilateral cleft nasal deformity using bilateral rim incisions to visualize the dislocated alar cartilages (40). An interdomal mattress suture brings together the middle crura; additional mattress sutures are used to adhere the ipsilateral lateral crus to its upper lateral cartilage. A suture is then used to draw together the alar bases into proper relationship—(interalar distance <25 mm)—recreating the nasal sills; a suture is also placed through the dermis of the alar bases to underlying muscle. Excess skin in the soft triangles is excised, narrowing the nasal tip, defining the columellar–lobular junction, elongating the nostril and narrowing the columellar waist. Excess vestibular mucosal lining is then excised to avoid a lateral vestibular web (Fig. 6A–E) (40).

Secondary Bilateral Cleft Nasal Repair

If only alar base repositioning is performed at the time of primary lip repair, secondary procedures, including columellar lengthening are inevitable (41,42). At approximately four years of age, an open rhinoplasty technique is used to manipulate the lower lateral cartilage into a more medial, normal relationship and is performed simultaneous to lip revision. Definitive rhinoplasty in the late teen years involves an open approach, with possible dorsal nasal augmentation with bone/cartilage, manipulation of the lower lateral cartilage for improved tip definition, possible septoplasty and turbinectomy.

Outcomes

Much of the advance in repair of the bilateral cleft nasal deformity has been in the progression from a separate secondary procedure, to staged primary, and then to a synchronous primary repair of the nasal deformity. In 1995, Mulliken published an anthropometric analysis comparing staged to synchronous repair of the bilateral cleft nasal deformity, in which he suggested that nasal tip projection and columellar length were not only improved in children who underwent single-stage repair, but approached normal (43). In 1998, Kohout (35) compared the methods of Trott (36,37) and Mulliken (40) for single-stage correction of the bilateral cleft lip and nasal deformities. Standardized photographs were used to measure pre- and postoperative facial proportions and angles. The nasolabial angle, nasal tip angle, and nasal width were wider than normals in both techniques. Nasal tip projection was greater than normals in both techniques, and was significantly greater in Mulliken's technique. Mulliken's technique also resulted in a normal ratio of columellar width to nasal width, philtral width to nasal width, and approached normal in the ratio of columellar length to nasal tip projection.

Our preferred technique for addressing the nasal deformity in the bilateral cleft patient is tailored to the extent of the deformity. A child with a more minimal nasal deformity (Fig. 7A) requires a less aggressive approach during primary repair, but may still require columellar lengthening (Fig. 7D) and definitive rhinoplasty during the late teen years (Fig. 7E and F). In a

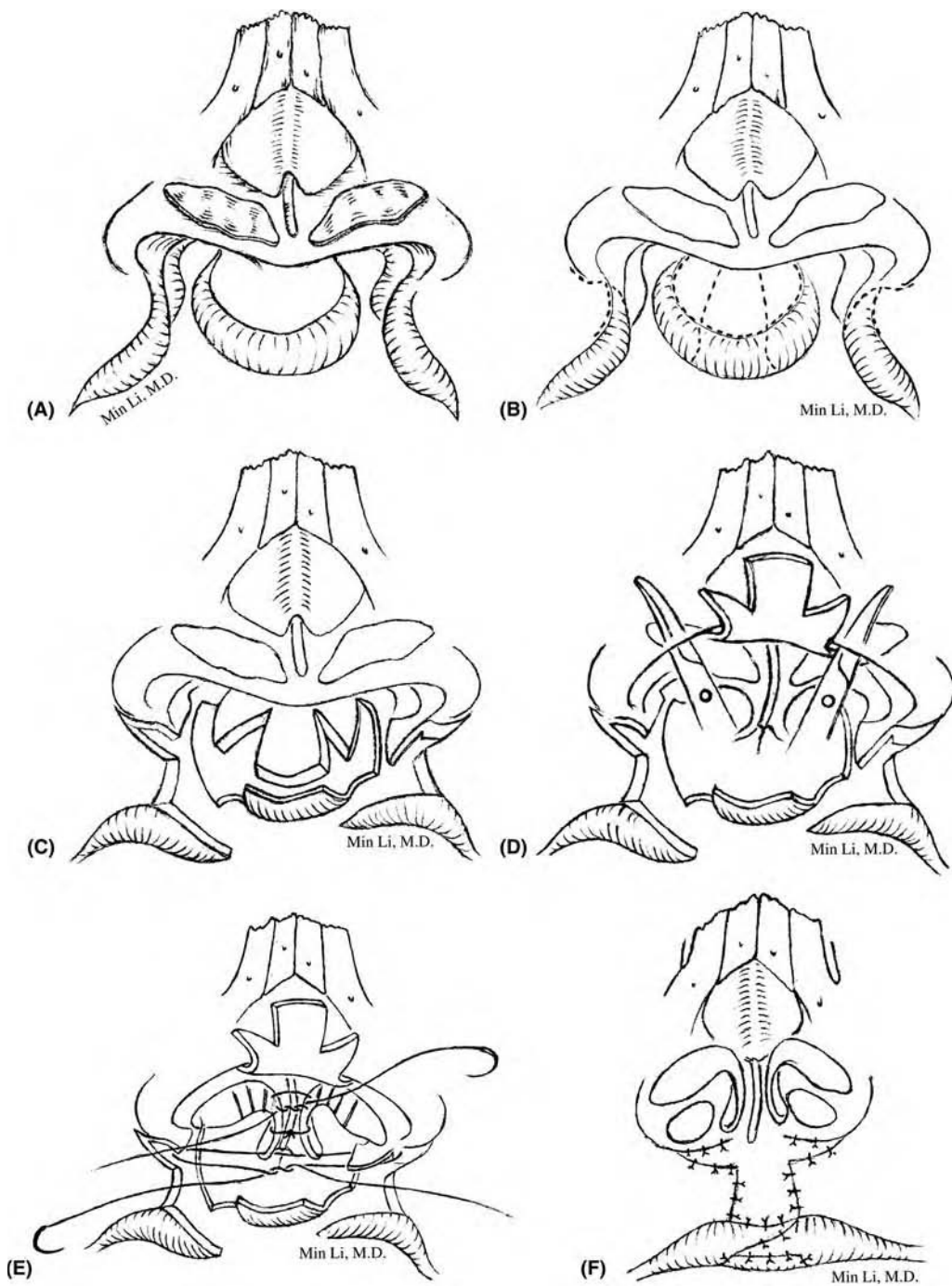


FIGURE 6 (A) Bilateral cleft nasal deformity. (B) Incision markings for the approach to the bilateral lip and nasal deformity repair. (C) Completed incisions similar to the technique of Mulliken. (D) Dissection through alar rim incisions to visualize the dislocated alar cartilages. (E) An interdomal mattress suture abuts the middle crura and genua. (F) Final closure of the incisions (40).

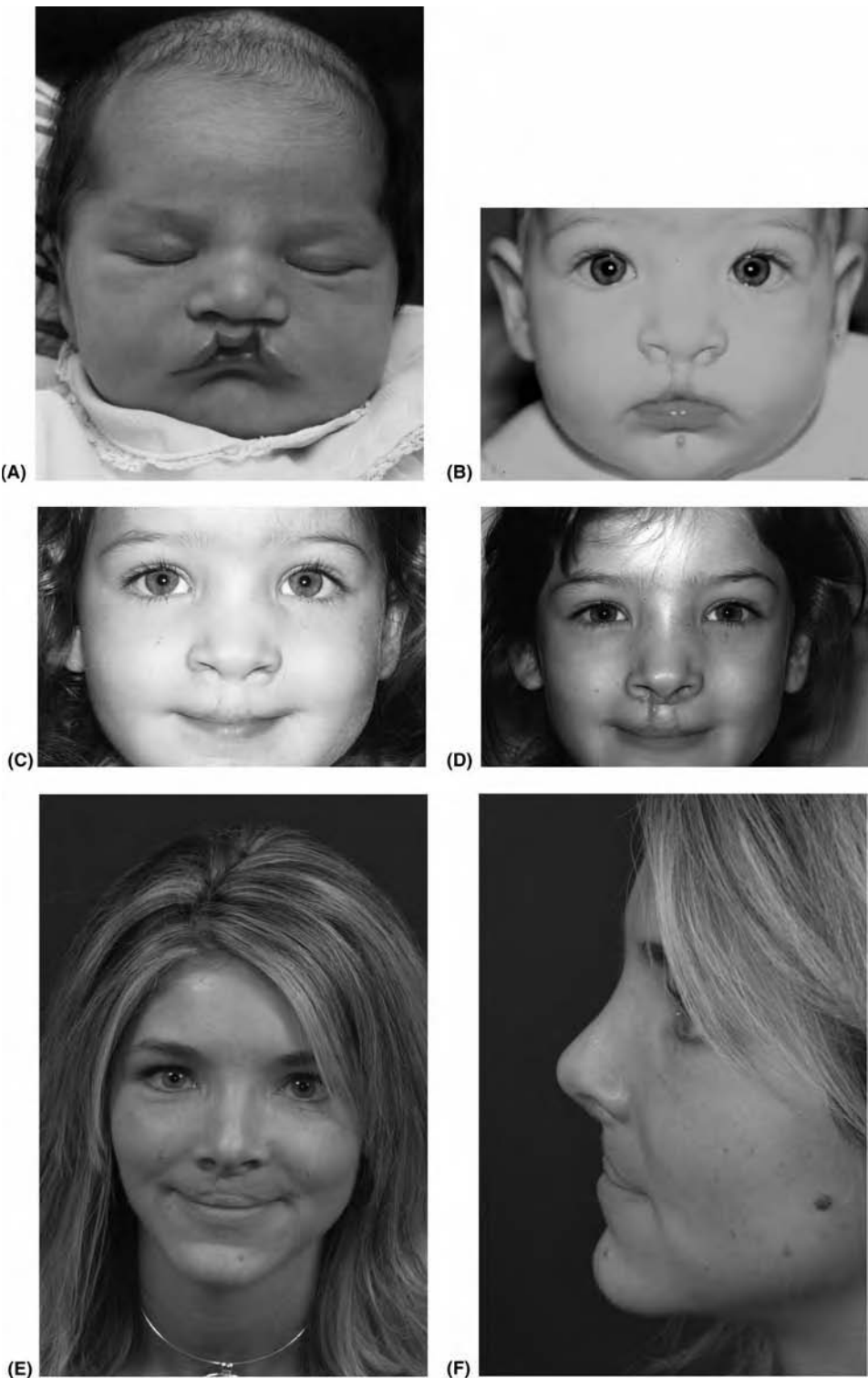


FIGURE 7 (A) An infant with bilateral incomplete cleft prior to repair. Note the minimal nasal deformity. (B) The same child after primary lip and nasal correction. (C) The child as a four-year-old. (D) The child after nasal revision, with columellar lengthening. (E) Frontal view at 22 years of age, following definitive rhinoplasty. (F) Profile view after definitive rhinoplasty.

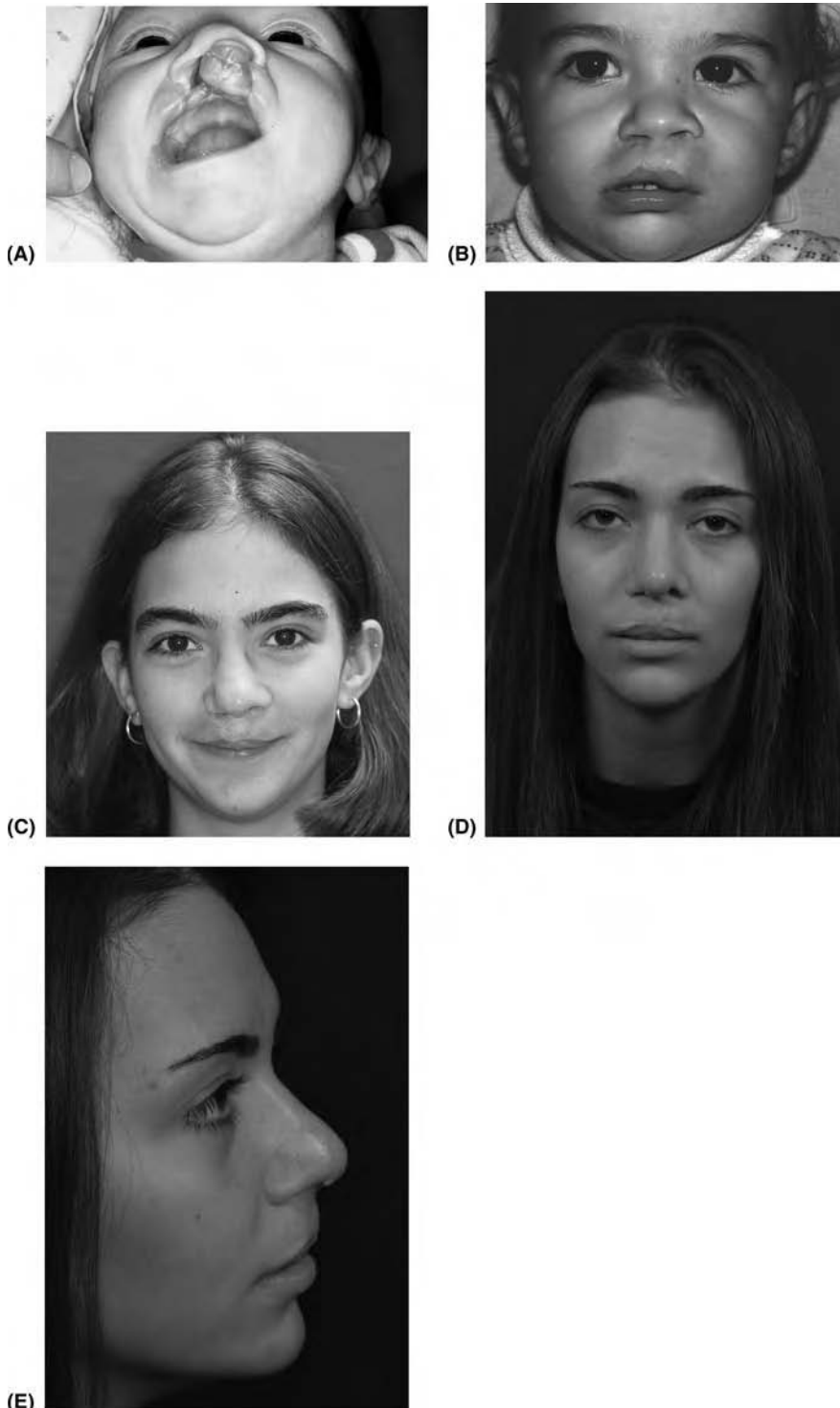


FIGURE 8 (A) An infant with a bilateral cleft prior to repair. Note the more severe nasal deformity than the child in Figure 7. (B) At three years of age, after primary lip and nasal repair, but before columellar lengthening. (C) At 12 years of age, after columellar lengthening, but prior to definitive rhinoplasty. (D) Frontal view at 19 years of age, following definitive rhinoplasty. (E) Profile view after definitive rhinoplasty as a teenager.

child with a more severe nasal deformity (Fig. 8A), a more aggressive approach to the nasal deformity is warranted at the time of primary repair. These children will require columellar lengthening (Fig. 8C) and definitive rhinoplasty with osteotomies, lower lateral cartilage manipulation and septoplasty (Fig. 8D and E).

CONCLUSION

The ideal time for cleft rhinoplasty is increasingly shifting in favor of early primary repair of the nasal deformity. With adequate long-term follow-up of patients after early repair, the criticism that early manipulation of the cleft nasal cartilage leads to growth attenuation has been laid to rest. However, both early and delayed repair of the cleft nasal deformity can—in appropriate hands—lead to good results, and despite differences in timing strategies, optimal results often can only be achieved with additional secondary procedures.

SUMMARY

Historically, as advances were made in the approach to repair of the cleft lip deformity, cleft nasal repair was often relegated to a secondary surgery. Recent trends, however, have reversed this approach. Presurgical NAM has been popularized and been called the most significant advance in the management of the cleft nasal deformity. In addition, an increasing number of surgeons are advocating primary operative intervention for the cleft nasal deformity at the time of initial lip surgery. Proponents of secondary repair of the cleft nasal deformity still suggest that the infant cartilage is too fragile to manipulate and may result in growth inhibition of nasal structures. Favorable long-term outcomes of patients who have undergone primary repair of the cleft nasal deformity suggest that these concerns are overstated. Despite these trends, the multitude of techniques developed to manage the cleft nasal deformity suggests that no single method has proven uniformly superior to others. Within this context, we present the primary management of unilateral and bilateral cleft nasal deformity.

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21 | Skin Care (Peels, etc.)

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BENEFITS OF INCORPORATING AN ON-SITE SKIN CARE CLINIC

An on-site skin care clinic provides patients with a result-oriented skin conditioning process. This process is dedicated first to the prevention or delay of the need for surgical procedures and cosmetic dermatologic treatments that require a physician's direct participation in the procedure itself. Second, it provides patients with physician-supervised skin preparation to enhance the healing and, at the same time, screen patients for compliance. Third, this process enhances, maximizes, and helps maintain the results from the physician-performed services for many years. Fourth, a result-oriented skin conditioning process encourages repeat surgical referrals and/or generates new ones. These four main reasons demonstrate the need for an on-site skin care clinic.

The most important step for the physician is the staffing of the clinic. The skin care professional who runs the clinic makes the clinic. If you have a cutting-edge product, all the new machines, and the newest treatments, that is wonderful, but the person who runs the clinic is the most important element. Working for over 10 years in medically supervised skin care, we are still questioning what arrangement works the best for the patient, the supervising physician, and nonphysician clinicians. The last category includes a wide range of allied health professionals: nurse practitioners, physician assistants, and nonphysician operators such as beauty technicians or cosmetologists, and estheticians (1). All those in this last category need to maintain a current state license and practice within the scope of the license or certificate especially if they are performing services as an independent contractor. That places many different restrictions on what they can do for your patients. If the abovementioned professional is employed by the physician, the physician needs to realize that this presents a potential liability for the practice. The person in charge of a clinical skin care clinic has to have a pleasant personality, convey assertiveness, and possess a positive attitude. It helps if that person is well educated, eager to learn, and able to maintain and enhance education in the field of clinical skin care. The key is to have a professional that takes a position not as a job, but as a career. The ability to listen and communicate with sincere caring is essential. Some helpful information may be found by visiting www.surgery.org/skincare, the website for the Society of Plastic Surgical Skin Care Specialists, a voluntary, nonprofit organization "dedicated to the promotion of education, enhancement of clinical skills, and the delivery of safe, quality skin care provided to patients from the offices of plastic surgeons certified by or eligible to sit for examination by the American Board of Plastic Surgery or the Royal College of Physicians and Surgeons of Canada."

First, a results-oriented skin conditioning process may help the patients prevent further skin damage and delay the need for surgical procedures and invasive cosmetic dermatologic treatments. Many patients seeking treatments for skin rejuvenation have skin imperfections that sometimes only require adjustment in their current skin care regimen. Others come for a consultation because they desire to surgically correct their sun-damaged skin. However, in some cases, when gravitational forces are not yet involved, the surgeon will recommend a skin rejuvenation process with the help of a chemical peel, which remains the gold standard. There are also individuals of all ages with a long-standing practice of sun avoidance who come to seek advice and learn how they may further protect their skin and maintain healthy skin. A collaboratively created preventive skin care regimen will keep these people in the clinic for many years to come. This category of patients "likes their skin," and it is very important to remember: if

there is nothing to correct for them, then do not. These people came from word-of-mouth referrals from their peers or relatives who already participate in a results-oriented skin conditioning process, and they are active generators of the practice referral base. Here educational and follow-up appointments are the main focus. Providing them with a personalized skin care product is the key to success.

Second, should the patient choose to have a facial cosmetic procedure the goal is to accelerate the healing process. A physician-supervised skin conditioning program enhances the postoperative healing and helps to screen for patient compliance. For this purpose, pretreatments with tretinoin, hydroquinone, or other effective formulations to improve vascularity and exfoliate the skin were designed. "The ability for the self-renewal of the superficial layers of the skin allows the skin to maintain its barrier and to repair itself as a response to wound healing" (2). Therefore, skilled exfoliation is essential to start this process before surgery. Healing would thus be enhanced postoperatively. "Several growth factors, like transforming growth factors- α and fibroblast growth factor, may enhance wound healing" (3). The preoperative skin care program is tailored to the patient's skin care needs. We must be very careful in what is said or done with the patients so as not to contradict, disrupt, or confuse the doctor's instructions to the patient. "Choices of active ingredients depend on the patient's skin care history, and skin type" (4), and the result of superficial skin resurfacing. The response to this regimen helps to evaluate patients' compliance and it may help to predict how the patients' skin will respond during the healing phase.

During skin preparation, visible improvement is noted by the patient, and by people around them. It reinforces the patient's trust in the surgeon and the professional abilities of the staff. Preoperative treatments also help patients share their fears and insecurities, and it may help to relieve preoperative anxiety. A skin care clinic provides the type of environment that is nourishing and auspicious. Seeing the preoperative patient as a "biopsychosocial being" (5) helps provide all needed support for the patient. Although medical teams already have taken a complete history, during the skin care treatments patient may share other information that is important for the surgeon to be aware of.

Preoperatively, it also beneficial to evaluate the patient's makeup skills and, if desired, discuss the options for makeup, specifying that it may be used only after the surgeon allows its use postoperatively. Reinforcing camouflage makeup may cover bruising and discolorations, but it does not camouflage the edema. Techniques that may improve the appearance of edema. This need to be done professionally with the use of shadows and highlights. However, this will improve but not completely take care of it. For patients undergoing resurfacing techniques it is important to know that the removal of camouflage makeup may disturb the healing process. Reassurance that the skin care specialist and the doctor are available and just a phone call away should any question arise after the surgery brings a sense of comfort and lessens preoperative anxiety for the patient.

Third, this process enhances, maximizes, and helps to maintain the results from the physician-performed services for many years to come. Products used before the surgery are used after surgery as soon as the surgeon gives permission. Unfortunately, many surgeons still underestimate the need for follow-up with the skin care clinic after the patient is completely healed. Once the patient has invested in the surgical improvement, and the surgeon has invested his time and mastery in this patient's improved appearance, logically they both would wish to maintain it. Just as new landscaping always needs maintenance, results from surgical procedures should be cherished and maintained. During this very important step, the continued improvement in the skin is monitored and maintained with home care products in conjunction with properly timed moderate-strength treatments. A healthy skin maintenance program is an essential step and provides the skin with effective, long-term management designed to maintain the result.

Fourth, a results-oriented skin-conditioning process generates referrals to the practice. Patients with rejuvenated skin and great surgical results receive complements such as: *You look great . . . your skin is glowing . . . These eye shadows are very becoming to you, you look rested.* For the surgeon, this means increased patient satisfaction and new referrals. With only great surgical results patient would hear: *That is a nice facelift.* This may sound like a great compliment to the surgeon, but patients prefer not to hear this as a compliment. In fact, the patients who participate in the skin preparation program in our practice would be really displeased to hear a compliment from someone outside our surgical practice. If the surgeon has difficulty in

referring patients back to the skin care clinic, just ask them what kinds of compliments their patients like to hear. It is true that a facelift can elevate skin, but then it still looks like elevated old, sun-damaged skin. Patients with the best looking skin receive more compliments on their appearance and that brings more business to the surgical practice. If the surgical result looks good but the skin was not rejuvenated, people compliment less, and there are markedly fewer referrals because the overall result is not complementing. Old sun-damaged skin with a facelift is not a finished product. Rather, a finished product includes a great surgical result and well-maintained, rejuvenated skin.

SKIN CARE CONSULTATION

The initial appointment is very important. A skin care consultation starts with an exploration of a patient's goals and expectations. Listening to the patient and observing nonverbal behavior is the best time to assess their skin condition. Evaluation of skin type, texture, aging changes, dyschromias, and thickness is important at this time. The information on the current skin care regimen is gathered and skin analysis is performed. Many offices also use a skin classification system. There are many classification systems that are widely accepted such as Fitzpatrick's skin types, photoaging classification by Glogau, and Rubun's system. A skin care professional needs to be familiar with all these systems but use only the system that is used in the office. Sebaceous activity evaluation is an important part of this assessment since it can significantly modify the resiliency of the skin to various skin care and peeling agents. Since dyschromias are the most common skin rejuvenation concern and its improvement is frequently the primary patient goal, its degree, depth, and etiology are evaluated as well. Pigmentary changes in photoaging skin are different from patient to patient. The etiology of pigmentary changes includes genetic predisposition, exposure to UV radiation, pregnancy, medication regimens including oral contraceptives, and other photosensitive medications. A Wood's lamp helps to determine the location of the pigment. "Treatment is then dictated by choosing the appropriate modality to penetrate to a depth from superficial peels to deeper peels with the end point in the papillary dermis" (6). A plan of action is designed with the patient at this time.

Pretreatment

Collaborative preprocedural preparation of the patient may include oral antibiotics, antiviral agents, and topical exfoliators used for two to six weeks. Light peels that only injure the stratum corneum often require no preprocedure prophylaxis, whereas deeper peels may place the susceptible patient at a higher risk of potential herpetic outbreaks and should be covered with an appropriate antiviral agent.

TREATMENTS

The treatments are an important part of the process. Once the goal is established, starting slowly with consistent results is a better approach than to have red, peeling, flaky, and irritated skin. Everybody involved needs to understand what can be corrected and what cannot be with any depth of injury, and need to keep in mind the liability issues that may arise with the application of chemical agents. Again, practicing within the scope of one's license cannot be overemphasized. "The process of skin rejuvenation has a long and well-documented history of safety and efficacy. Procedures are performed with relative ease, the materials are inexpensive, and patients benefit from a relatively rapid recovery time" (7). Chemical peeling agents are classified according to the depth of penetration and to the expected injury. Superficial (epidermal injury), where the sloughing of the stratum corneum occurs, improves skin texture by stimulating the growth of a thicker epidermal layer. A medium depth peel causes superficial dermal injury to the papillary dermis and a deep peel causes mid-depth injury to the reticular dermis. A problem arises between the practitioner and patients when patients start thinking that a higher concentration or lower pH of the agent will produce better results. At this time in the skin care clinic, the goal is reinforced to have smooth, clear, and moist complexion with minimum discomfort and side effects. It is also safer for everyone to have slow changes toward a healthy skin than to

be aggressive. Chemical peels are most often used to improve actinic damage, remove dyschromias, smooth out fine wrinkles, flatten mild scarring, treat acne, and treat superficial skin lesions. "The degree of injury is dependent upon the chemical agent used, its concentration, the time of application before neutralization, and the number of coats placed at that session" (8).

Many authors agree that even though the depth is determined by the type of chemical peel, the same chemical agents, the same concentrations, and the same pH are able to perform at different depths on different individuals or even the same patient. Because it is true that the injury or the depth of the peel depends on the penetration of the agent, the patient's preparation at home before the treatments, the immediate skin preparation before application of the chemical agent, and the technique affect the depth of the peel. Several chemical agents are currently used to perform exfoliation. These include trichloroacetic acid (15–30%), alpha-hydroxy acids (AHA) [e.g., glycolic acid (GA) 40–70%], and Jessner's solution (14% lactic acid, 14% resorcinol, and 14% salicylic acid), salicylic acid, a beta-hydroxy acid, and tricarboxylic acid 25% to 35%. "Beta-hydroxy acid peel has distinct advantages for resurfacing moderately photodamaged facial skin. Patients have treatments singly and multiply at four-week intervals. The benefits are fading of pigment spots, decreased surface roughness, and reduction of fine lines" (9). "The superficial 20% and 30% salicylic acid peels were safely and effectively used for skin types V and VI. Salicylic acid peels offered significant adjunctive benefit when treating acne vulgaris, oily skin, enlarged pores, textural changes, postinflammatory hyperpigmentation, and melasma" (10). "Superficial GA peels are a good adjunct to topical therapy in melasma in dark-complexioned patients as they accelerate the clinical response and are well tolerated if used with topical combination therapy" (11). It was concluded, however, that they must be used judiciously and under supervision. And, caution is the guidance here. These findings corroborate those of Van Scott and Yu (12), who found that "GA stimulated the synthesis of new collagen." "Repeated and regular applications of GA to the face have been shown to diminish fine facial wrinkles significantly" (13). Another study compared "mechanical exfoliation with a Loofah sponge to GA applications found that by 10 weeks significant improvement was observed in more than 95% of the GA-treated hands" (14). Another modality of superficial to moderate depth peel is the "Golden Peel" (resorcin 53%, glycerin monostearate 5.0%, cetyl alcohol 5.0%, dionized water 37.0%). According to the author, "this peel does not require taking time off to heal" (15). Tretinoin peeling (1–5% tretinoin applied twice a week) is another superficial peel based on the histologic findings. By looking at the histologic samples it was determined that patients with actinically damaged skin who underwent these treatments reached the "same excellent results within 2.5 weeks as in patients who had used Retin-A daily for approximately four to six months" (16). Other modification is GA 70% and 5-fluorouracil (5-FU), the fluor-hydroxy pulse peel. This combination was applied weekly to all patients for an eight-week period. "The fluor-hydroxy pulse peel applied in a pulse dose regimen not only provides cosmetic improvement, but more importantly has a therapeutic effect on ablating premalignant actinic keratoses" (17). "Comparison of 35% TCA-treated skin with 70% GA-treated skin examined histologically at different times revealed similar changes in the papillary dermis connective tissue proteins, epidermal necrosis seen only with TCA, and reversion at two years post peel to pretreatment appearance" (18).

Microdermabrasion was developed in 1985 and has been a very popular modality of skin exfoliation. It is performed in physicians' offices, beauty salons, skin care clinics, nail salons, tattoo salons, piercing salons, and even private homes. The exfoliation is dependent upon the particle flow rate and vacuum pressure. The operator controls the depth of injury with the movement of the hand-piece and the number of passes. "Variations in effect may be related to vacuum power (negative pressure setting), particle type and size, the speed and number of passes, and the angle of the hand piece" (19). "Telangiectasia and erythema may be worsened or brought out by microdermabrasion. These effects may be temporary or permanent due to the localized trauma of ablation and suction. Patients with acne rosacea should be discouraged from undergoing microdermabrasion, especially in the central face" (20). Some machines use alkali substances like salt and soda as a particle. Skin resistance to alkali is relatively poor and the response to strong alkali is frequently overlooked since there is not an immediate burning and stinging. There are only small studies performed to show the efficacy of this modality. The study of "14 patients who underwent the treatments over 12 to 14 weeks demonstrated improvement in roughness, mottled pigmentation, and overall improvement of the skin.

Histologic finding demonstrated homogenization of stratum corneum and it improved some aspects of photoaging" (21). "Clinical effects include improvement in fine wrinkles, decreased size of dilated pores, decreased sebum content, and a slight increase in skin roughness. Whether these changes are temporary or longer lasting may be related to the depth of injury (the aggressiveness of the treatment), which may be operator-specific as well as microdermabrasion unit-specific. Histologic benefits of microdermabrasion have included fibroblast stimulation and new dermal collagen deposition" (22). "Initial changes include epidermal thickening and normalization of the stratum corneum. With continued use, thickening of the papillary dermis with increased deposition of collagen and elastin and an increase in fibroblasts occur. Additionally, an inflammatory response including microcirculatory changes in the reticular dermis become evident, which may produce the clinical effects seen with microdermabrasion" (23).

SKIN CARE PRODUCTS

The most important part of understanding skin care product claims is to differentiate between the studies done for one particular ingredient and the final formulation. Many times the results of the studies done for one particular ingredient are not equitably transferred to final formulations. It is critically important for the practitioner to have an ability to thoroughly analyze and understand why one product is superior over the other. If the skin care clinic is here to stay, then the product that is offered needs to be researched, and the decision needs to be based on more than just the commercials from the representative of manufacturer. The company representatives are your best resource in helping to gather all of the needed information. They like to be challenged because they learn too.

Sunscreens

The value of an appropriate, effective sunscreen cannot be underestimated. The instruction on how to use the sunscreen properly is essential since numerous studies have shown that many patients use them incorrectly. Sunscreen education must emphasize that the use of a sunscreen does not allow longer exposure to the sun. There are many different sunscreen products on the market. The composition of the vehicle of a sunscreen product is a very important factor in determining the effectiveness of the product. The FDA regulates sunscreens as drugs, and for further information the reader is referred to the FDA. If the patient leaves your office with only one skin care product, it should be a sunscreen. Products with microfine zinc oxide are an effective and a safe sunscreen. Sun protective factor (SPF) is the only measure of UVB protection, and UVA protection measures have not been officially established by the FDA. It was shown that "microfine titanium dioxide is less effective than microfine zinc in protecting against long wave UVA" (24).

There is a new generation of UV absorbers and vehicles. An encapsulated-in-glass microparticles organic sunscreen is an exciting new technology. However, so far, formulations that are on the market are not favorable for postoperative patients. Again, it is important to evaluate the whole formulation, not just an ingredient. It is very important to educate the patients to follow the recommendation that sunscreen be reapplied 20 minutes after the initial application. "This is based on the premise of compensation for initial poor application. A mathematical model suggests that reapplication of the sunscreen at 20 minutes into a six-hour period of sun exposure resulted in less cumulative exposure than a reapplication at two or four hours" (25). Avoidance of the sun is always one of the best tools. Kligman has demonstrated that "complete avoidance of sunlight can reverse some of the histologic signs of photoaging" (26).

Tretinoin

As a major part of a pretreatment plan, tretinoin accelerates the healing process. The study showed "after seven days, 75% of the tretinoin-pretreated hemifaces were completely healed, as opposed to 31% of the placebo-pretreated hemifaces" (27). Topical retinoid may provide some protective benefits. Since it "inhibits induction of activatorprotein-1 and matrix metalloproteinases" (28). Applying retinoic acid to the skin prior to sun exposure "prevents degeneration of retinoid receptors. It was decided that skin damage by UV light is partially due to loss of

retinoid receptors in the cellular nuclei" (29). "Another study showed that photoaged skin treated with topical tretinoin demonstrated an increased number of anchoring fibrils. The decrease of the collagen 4 in these fibrils contributes to wrinkle formation and skin fragility" (30).

Alpha-Hydroxy Acids

The popularity of this ingredient is very well known. The skin's response to AHA depends on the condition of the skin, pH, the vehicle, duration of contact with the skin, preparation of the skin, and the site being treated. This is a very beneficial ingredient. Most preparations found in physicians' offices contain between 8% and 15% AHA. "A double-blind, vehicle-controlled study of 8% GA and 8% lactic acid demonstrated a significant improvement in the overall severity of photodamage, mottled hyperpigmentation, and sallowness in the treatment groups at five months. There was no significant improvement in wrinkles" (31). The studies demonstrated that topical GA provides a photoprotective effect and acts as an antioxidant. The studies show that "pretreated skin yielding an SPF of approximately 2.4, and when GA is applied to irradiated skin; it accelerates the resolution of erythema. The data obtained from both studies support the hypothesis that GA acts as an antioxidant" (32). The effects of GA in the other study show that "epidermal and dermal remodeling of the extracellular matrix occurs with GA treatments when forearm skin was treated with 20% GA lotion for three months" (33). Ditre et al. demonstrated a "significant increase in overall epidermal thickness that appeared to be secondary to augmented synthesis of glycosaminoglycans and collagen. In addition, they found significant reversal of basal cell atypia, dispersal of melanin pigmentation, and a return to a more normal rate pattern" (34). The AHA and polyhydroxy acids (AHA/PHA) are known to provide significant cosmetic benefits to photoaged and hyperkeratotic skin. Lactobionic acid is a new polyhydroxy bionic acid ingredient being introduced into skin care. Results indicate that "lactobionic acid is an effective antioxidant since it is capable of preventing oxidation of the hydroquinone when lactobionic acid was compared to other known antioxidant substances" (35).

The cosmetic benefits of lactobionic acid suggest that it provides antiaging and cell turnover benefits to skin and may be useful in enhancing wound healing. "Preliminary findings suggest that lactobionic acid causes a measurable increase in skin thickness. Similar previous findings have correlated well with reversal of histologic symptoms of skin aging" (35,36).

Topical Growth Factors

The application of a mixture of topical growth factors was studied in 14 patients who applied a gel containing a mixture of eight different growth factors to photodamaged facial skin twice daily. It was found that this preparation "may stimulate the repair of facial photodamage resulting in new collagen formation, epidermal thickening, and the clinical appearance of smoother skin with less visible wrinkling" (37).

Topical Vitamin C

Vitamin C took the posture of the fountain of youth several years ago. There is still a controversy as to the best vitamin C. "Topical 5% L-ascorbic acid (pH 3.0) produced clinical and statistically significant results in reducing the erythema within three weeks for patients with acne rosacea" (38). In a different study "topical vitamin C demonstrated reduced inflammation secondary to sunburn and it prevented UV immunosuppression in porcine skin" (39). "Vitamin C (ascorbate) has been shown in, in vitro studies to inhibit UV effects on cellular signal transduction" (40). Vitamin C definitely has a place in the skin care clinic, but one needs to understand that patients need to be educated on what they use and why. Here are some other skin care products:

Alpha-lipoic acid is a naturally occurring universal antioxidant that is soluble in water and oil, and shows protective effects. There is plenty of information available on this ingredient but not on the end product.

Copper peptides are recognized for their ability to speed up the wound healing process. Dimethylaminoethanol is a topical preparation and is said to be able to improve skin firmness and lift sagging skin.

Green tea extract was applied to the skin of human volunteers 30 minutes prior to simulated UV exposure. "It was concluded that polyphenolic extracts of green tea are effective chemopreventive agents for many of the adverse effects of sunlight on human health and may thus serve as natural alternatives for photoprotection" (41).

Pro-Nad: "Evidence suggests that NAD(P)H may act as a direct antioxidant" (42).

Vitamin E and the cosmetic appearance of scars. The study showed that there was no benefit to the cosmetic outcome of scars by applying vitamin E after skin surgery, and that "the application of topical vitamin E may actually be detrimental to the cosmetic appearance of a scar." In 90% of the cases in this study, topical vitamin E either had no effect on or actually worsened the cosmetic appearance of scars. Of the patients studied, 33% developed a contact dermatitis. It was concluded that "the use of topical vitamin E on surgical wounds should be discouraged" (43).

FORMULATION FOR HYPERPIGMENTATION

Hyperpigmentation disorder remains a challenge. Formulations historically containing hydroquinone 4.0% are effective. Recent comparative studies performed with the help of 641 adult patients with four formulations—tretinoin 0.05%, hydroquinone 4.0%, and fluocinolone acetonide 0.01% (RA + HQ + FA), dual-combination agents tretinoin plus hydroquinone (RA + HQ), the tretinoin plus fluocinolone acetonide (RA + FA), and hydroquinone plus fluocinolone acetonide (HQ + FA)—concluded that at week 8 "a 75% reduction in melasma/pigmentation was observed in more than 70% of patients treated with RA + HQ + FA compared with 30% in patients treated with the dual-combination agents" (44).

CONCLUSION

Regardless of why patients come to visit the surgical practice, it is important to expose them to the available skin care services. It is a service that helps the surgical results look the best and it generates new referrals to the surgical part of the practice. The whole practice is there to help patients look better; therefore, choosing the correct, scientifically supported skin care products and services is a very important part of the practice. There are many other ingredients and treatments available. We encourage anyone who operates a skin care clinic to stay current with the scientific literature regarding skin care. This will help to clear up confusion and prepare the answers to possible questions that our very well-educated patients may have.

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22 | The Subperiosteal Facelift

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INTRODUCTION

The subperiosteal techniques initially described by Tessier for the treatment of congenital craniofacial abnormalities have revolutionized the treatment of the aging face. Close to a decade after suggesting that rejuvenation of the cheek and forehead could be accomplished in a subperiosteal plane, Tessier published his landmark paper, "Lifting facial sous-perioste" in the French literature (1,2). Tessier advocated the subperiosteal approach as a method to treat early signs of facial aging in young and middle-aged patients. Adopting Tessier's approach, Psillakis, Ramirez, and others refined the technique and demonstrated that the subperiosteal facelift could be applied across the full spectrum of facial aging (3,4).

Despite the success of this open subperiosteal approach, opponents of the technique voiced concern over the high rate of nerve injury and the protracted facial edema associated with the procedure. The introduction of the endoscope in the treatment of facial rejuvenation ushered in a new era in aesthetic surgery. Treatment of the forehead could now be performed without the need for the cosmetically inferior bicoronal incision. With the use of the endoscope, the subperiosteal midfacelift resulted in reduced postoperative facial edema, minimal injury to the facial nerve branches and improved aesthetic correction of the sagging cheek structures (5–7). Today, subperiosteal undermining of the upper, middle, and lower face can provide a means for repositioning the sagging facial soft tissues in addition to augmentation or reduction of the craniofacial skeleton. The subperiosteal techniques described in this chapter provide the basis of modern aesthetic craniofacial surgery.

THE ANATOMIC BASIS FOR THE SUBPERIOSTEAL FACELIFT

Facelifting in the subperiosteal plane has proven to be an effective method for facial rejuvenation. The technique is based on an improved understanding of the anatomic changes associated with the facial aging process. Three characteristic features of the facial aging process are: (i) impairment of collagen repair mechanisms, (ii) gravitational migration of the soft tissues, and (iii) loss of skeletal volume. Impaired collagen repair mechanisms result in thinning of the skin and loss of elastosis, leading to rhytid formation. In addition, deep connective tissue support of the skin, fat, and muscle deteriorates. Gravitational forces lead to migration of fat deposits and sagging of the soft tissues. The skeletal framework of the face undergoes an overall reduction in volume with age. Furthermore, loss of dentition tends to exaggerate the age-related reduction in bone volume.

In an effort to reverse the effects of facial aging, traditional rhytidectomy techniques pull and tighten the sagging tissues. These techniques can effectively address the first two characteristic features of facial aging (i.e., rhytid formation and descent of the soft tissues). However, they do not adequately address the volumetric changes associated with aging. In contrast, the subperiosteal approach relies on repositioning the skin and soft tissue envelope and, more importantly, remodeling of the soft tissue and bony structures. This approach stresses the restoration of the facial volume that is associated with a youthful appearance. In addition, the subperiosteal rhytidectomy technique (open or endoscopic) is the only technique that modifies the position of facial muscle insertion on the bony skeleton. This unique characteristic provides improvements in facial expression not seen with alternative rhytidectomy procedures.

INDICATIONS FOR THE SUBPERIOSTEAL FACELIFT

Patients with considerable aging and ptosis of the central facial structures can benefit from the subperiosteal facelift approach. The areas where facial aging is most evident—the eyebrows; the eyelid commissures; the nasoglabellar soft tissues; the nose; the nasolabial folds; the cheeks; the angle of the mouth; and the jowls—can be effectively treated with this approach. In addition, other signs of periorbital facial aging, such as tear trough deformities and deep infraorbital hollows, can be corrected with these subperiosteal techniques.

The subperiosteal approach is particularly advantageous for patients undergoing secondary or tertiary facelift procedures. Scar tissue formation and blurring of the anatomic structures can make dissection in these patients difficult for even the most skilled surgeons. Approaching these cases through a “virgin” subperiosteal plane can prevent nerve injury and provide improved soft-tissue augmentation. The subperiosteal technique is preferred in those patients who require immediate skin resurfacing (e.g., deep chemical peel or carbon-dioxide laser peel). Patients requiring soft-tissue augmentation via fat grafting also benefit from a subperiosteal approach. Deep rhytids can be filled and residual soft-tissue asymmetries can be addressed at the completion of the subperiosteal facelift. Subperiosteal facelifting techniques have also proven effective in patients who refuse to quit smoking. Though we strongly advocate smoking cessation before and after surgery, patient noncompliance has not been shown to be detrimental to the results of the endoscopic facelift in our practice. In addition, patients who demonstrate skeletal and soft-tissue disproportion can perhaps benefit most from the subperiosteal lifting techniques. The exposed bony structures can easily be augmented or reduced as needed. Finally, the authors recommend this approach in all patients with alloplastic facial implants that require implant removal or exchange.

METHODS OF SOFT-TISSUE SUSPENSION

The key facet to the subperiosteal rhytidectomy approach is the suspension of the drooping soft-tissue structures and correction of soft-tissue deficiencies (e.g., mobilization of Bichat's fat pad to augment deficient malar areas). Suspension of the mobilized soft-tissue envelope provides a considerable increase in facial volume that cannot be achieved with standard rhytidectomy approaches (Fig. 1). During the evolution of the endoscopic rhytidectomy technique, a variety of suspension methods were attempted. Resuspension of the soft tissue via periosteum to periosteum or periosteum to fascia failed to provide adequate support. However, strong support could be obtained from fascia to fascia, fat pad-periosteum to fascia or bone,

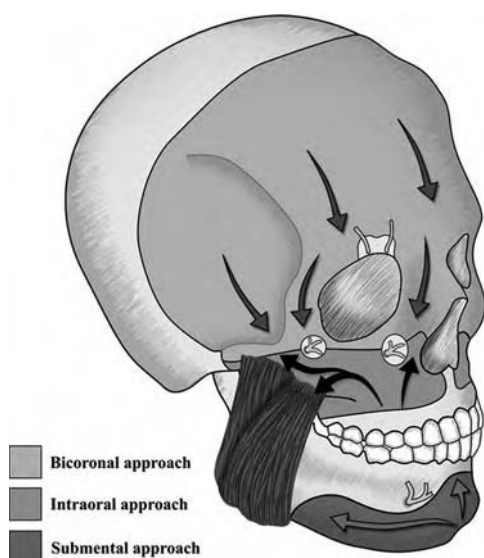


FIGURE 1 The various methods of deep soft-tissue suspension to maintain the position of the elevated structures during soft-tissue remodeling are shown above. Modifications to these described techniques have evolved into the current three-suture suspension technique described in this text.

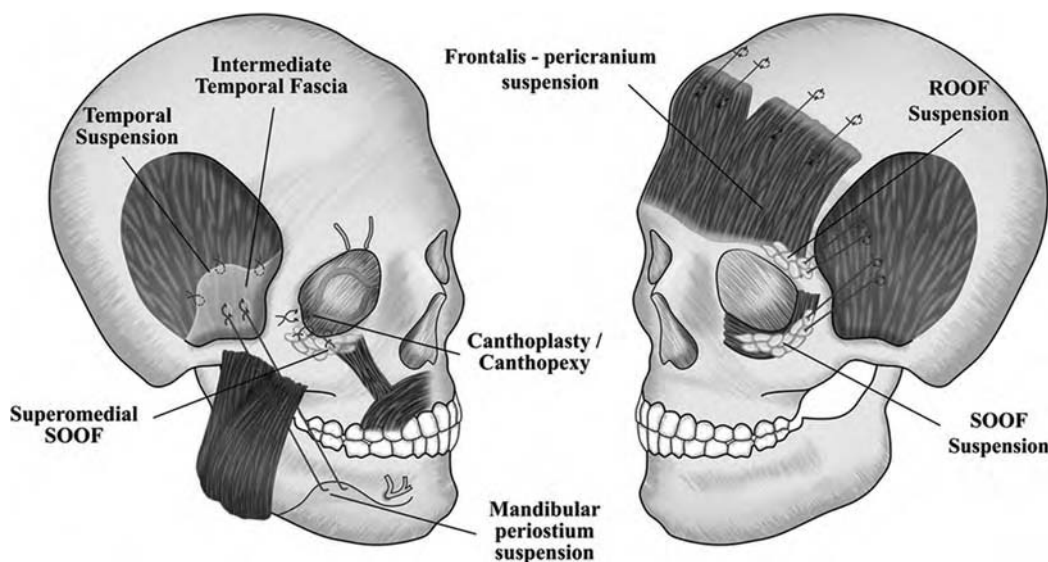


FIGURE 2 This schematic diagram demonstrates the extent of soft-tissue mobilization possible with subperiosteal undermining. Full tissue release can be accomplished with either an open or endoscopic approach. The mandibular dissection can be achieved through either an intraoral or submental incision. *Abbreviations:* ROOF, retro-orbicularis oculi fat; SOOF, suborbicularis oculi fat.

and ligament to fascia or bone. The authors commonly use the later methods to anchor the suspended soft tissues.

Described anchoring methods associated with the subperiosteal rhytidectomy approach include the galea-periosteal layer at the bicoronal or hairline incision (8), lateral canthal ligament (2,9), retro-orbicularis oculi fat pad (ROOF)-periosteum (10), deep suspension using temporal fascia (4,11,12), direct midface suspension using suborbicularis oculi fat pad (SOOF) with its underlying periosteum (13) and levator labii superioris attachment (14) (Fig. 2). It is interesting to note that these suspensory techniques provide the basis for techniques such as barbed and nonbarbed suture threading lifts currently en vogue. Despite the popularity of these procedures, the reader should understand that the subperiosteal suspension techniques described in this chapter provide stronger and more permanent results.

THE OPEN SUBPERIOSTEAL FACELIFT

The open subperiosteal facelift can be approached through a standard bicoronal incision or a modified hairline incision. The modified hairline incision is preferable in patients with excessively long foreheads (>8 cm) or those with significant alopecia (e.g., those with a receding hairline). The authors recommend using the “stealth” or wavy-line incision rather than the traditional straight-line approach. The zig-zag nature of the “stealth” incision line allows resultant alopecia in the scar to be easily camouflaged with most hair styles. In contrast, standard bicoronal incisions force the hair to part in a more conspicuous manner, making the incision line difficult to camouflage.

The dissection begins at the scalp incision line and continues laterally under the temporoparietalis fascia. The lateral extent of the dissection is to 1.0 cm above the zygomatic arch. Centrally, the dissection continues to the level of the superior orbital rim. The supra-trochlear and supraorbital nerves should easily be identified during the dissection around the orbital rims. Medially, the dissection extends toward the nasoglabellar angle and downward elevating the nasal periosteum. The authors recommend entering the periorbital region, releasing the arcus marginalis widely to facilitate brow repositioning. Mastery of the dissection technique comes with a clear understanding of the anatomic structures found in the temporoparietal region. Please refer to the schematic diagram and cadaveric dissections shown in Figures 3–6.



FIGURE 3 The artist's drawing above depicts the anatomic fascial layers of the temporal region approaching and overlying the zygomatic arch. *Abbreviations:* DFP, deep temporal fat pad; DTF, deep temporal fascia; IFP, intermediate temporal fat pad; ITF, intermediate temporal fascia; STF, superficial temporal fascia.

To elevate the periosteum along the zygomatic arch, an incision is made through the external layer of the temporal fascia. The fat pad between the superficial and deep temporal fascia can be elevated as part of the flap. This facilitates mobilization of the entire zygomatic arch periosteum and protects the frontal branch of the facial nerve from injury. The lower dissection proceeds through a gingival buccal sulcus incision. Care must be taken to identify and preserve the infraorbital nerves. The lateral dissection along the maxilla extends over the tendon of the masseter muscle. From this point, the dissection pockets of the temporozygomatic arch (upper) and the maxilla-zygoma-masseter (lower) are connected.

Patients requiring rejuvenation of the lower face can benefit from subperiosteal undermining of the mentum and inferior border of the mandible up to the insertion of the masseter muscle. The upward movement of the midface structures will transmit a concomitant lifting and pulling effect to the lower face soft tissues that have been undermined.

We do not routinely reposition the lateral canthal ligament. However, if repositioning is considered, the orbital rim periosteum is elevated superiorly, laterally, and inferiorly. Anchoring of the lateral canthus is achieved by transosseous fixation. Two holes are drilled through the superolateral aspect of the orbital rim, allowing suture fixation of the lateral canthus.

The mid and lower face structures are then suspended with 3-0 PDS sutures. Commonly, the suspension is accomplished with temporal fascia to temporal fascia anchoring, and SOOF-periosteum to temporal fascia. Secondary choices for anchoring include the ROOF-periosteum and the fibers of the masseter tendon left attached to the elevated cheek periosteum. The former is useful to decrease the likelihood of recurrent lateral hooding of the brow.

Upward movement of the soft tissue with the subperiosteal technique can lead to redundancy of skin in the lower face that responds well to standard cervicoplasty techniques. We prefer to address this skin redundancy with a periauricular incision that extends posteriorly

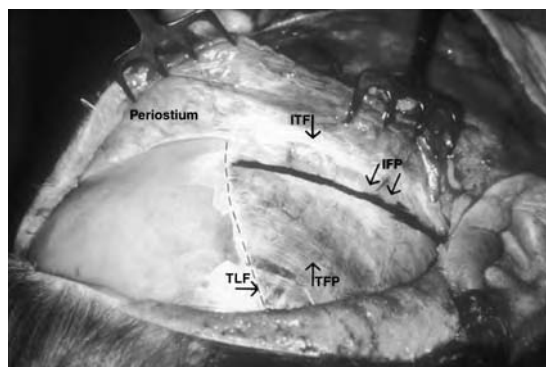


FIGURE 4 The cadaver dissection shows the intimate relationship of the ITF to the TFP. The IFP can be seen underneath the thin ITF. The dark line represents the decussation of the intermediate and deep temporal fascial layers. *Abbreviations:* IFP, intermediate temporal fat pad; ITF, intermediate temporal fascia; TFP, temporal fascia proper; TLF, temporal line of fusion.

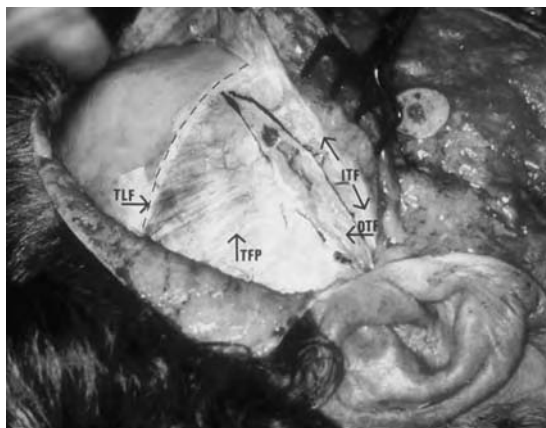


FIGURE 5 Division of the ITF and elevation of the ITFP reveals the most superior portion of the DTF. *Abbreviations:* DTF, deep temporal fascia; ITFP, intermediate temporal fat pad; ITF, intermediate temporal fascia.

into the occipital scalp. The advantages to this approach include improved remodeling of the cervicomandibular structures and augmented support of the central face soft tissues leading to the improvement of the nasolabial fold.

THE ENDOSCOPIC SUBPERIOSTEAL FACELIFT

The endoscopic facelift is founded upon the open subperiosteal approach described in the previous section. The endoscope allows a similar dissection to be performed utilizing minimal access incisions. Though the endoscopic subperiosteal rhytidectomy is a technically challenging procedure, excellent results can be achieved by adhering to basic surgical principles. Proficiency with the open subperiosteal technique should be achieved prior to any attempts at the endoscopic approach. The following section will describe the subperiosteal endoscopic forehead and midface procedures in detail.

SURGICAL TECHNIQUE

Endoforehead Procedure

The endoscopic forehead procedure involves the placement of four incisions in the scalp. The first two incisions are located approximately 2.0 cm on either side of the midline, 2.0 to 2.5 cm posterior to the hairline (Fig. 7). For patients with excessively long foreheads (>8 cm), these paramedian incisions are placed directly at the hairline. It is important to keep the forehead incisions as anterior as possible. Otherwise, visualization and dissection in the glabellar region will be compromised. The next set of incisions is located in the temple region, bilaterally, 2.0 cm

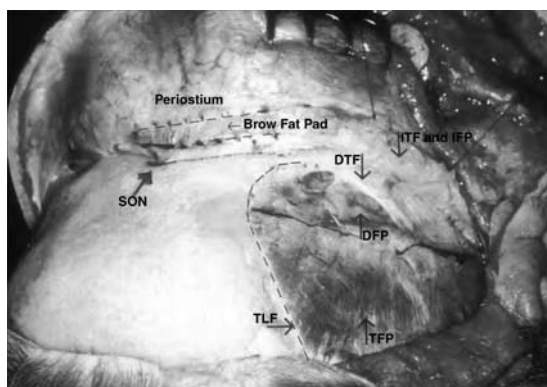


FIGURE 6 Deeper dissection reveals the clearly distinct intermediate and deep temporal fascial layers with the respective IFP and DFP fat pads. *Abbreviations:* DTF, deep temporal fascia; IFP, intermediate temporal fat pad; ITF, intermediate temporal fascia; TFP, temporal fascia proper; TLF, temporal line of fusion.

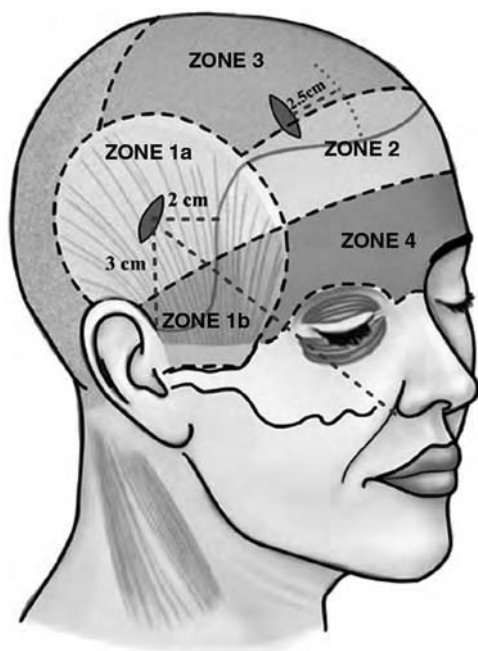


FIGURE 7 Safe dissection during the endoscopic procedure is aided by following the zone system shown in the above diagram. Vital neurovascular structures located in zones 1b and 4 mandate that strict endoscopic dissection be performed in these regions. Also note the location of the endoscopic incisions.

posterior to the hairline. The incisions should be directed parallel to the hair follicles to prevent unnecessary alopecia, postoperatively. Each incision should measure 1.5 cm in length.

Prior to surgical dissection, local anesthesia using 50cc of 0.5% lidocaine with 1:200,000 epinephrine is diffusely distributed in both a subcutaneous and subperiosteal fashion. Early administration of the anesthetic will provide maximal hemostasis required during endoscopic visualization.

To better understand the operative procedure, the forehead is divided into four zones (Fig. 7). Zones 2 and 3 can safely be dissected in a “blind” fashion without the need for the endoscope. Due to the vital structures located in zones 1 and 4, however, dissection in these zones mandates the use of the endoscope at all times.

The endoscopic procedure begins with the incision in the temporal area, designated as zone 1. This incision is located perpendicular to a tangent drawn from the nasal ala to the lateral canthal tendon and is 2 cm inside the temporal scalp as can be shown in Figure 7. A 1 cm incision is made through the skin and subcutaneous tissue, deep into the superficial temporal fascia. Dissection continues inferiorly remaining above the intermediate temporal fascia. The initial dissection can be performed blindly in a circumferential fashion for approximately 1 to 2 cm. With the tissues elevated, a silastic port protector is inserted and the remainder of the dissection is performed under endoscopic control.

An elevator is used to dissect to the temporal line of fusion superiorly. The elevator is then used to score and elevate the periosteum 1.0 cm medial to the temporal line of fusion. This is continued superiorly through zones 4, 2, and 3, respectively. This dissection will aid in the connection of the temporal and frontal pockets, later in the case. Dissection continues from the temporal incision in an inferior and medial direction around the lateral orbital rim. During the course of this dissection, several temporal veins will come into view. Temporal vein 1, situated in the region of the zygomaticofrontal suture, is usually sacrificed. Temporal vein 2 is encountered while dissecting toward the zygomatic arch. Branches of the zygomaticotemporal nerve may be identified during this dissection. Both temporal vein 2 and the branches of the zygomaticotemporal nerve should be preserved whenever possible. Preservation of these structures is facilitated with a blunt rounded tip 0 (zero) elevator (Fig. 8). As the procedure progresses inferiorly, the dissection plane moves from temporal fascia proper to the intermediate temporal fascia. The intermediate temporal fat pad will be visualized through the thin intermediate temporal

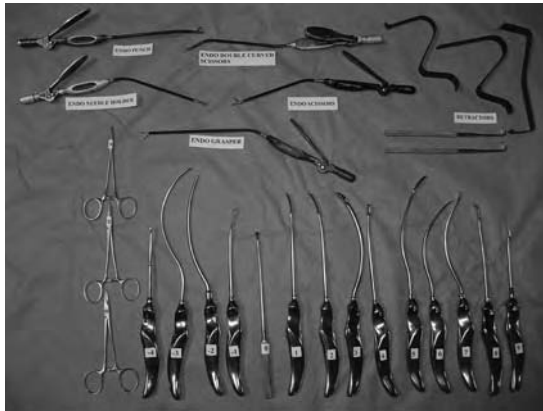


FIGURE 8 A broad range of instruments have been designed specifically for the endoscopic subperiosteal facelift. Of the periosteal elevators shown at the bottom, the instruments labeled 1, 0, 2, 4, 8, and 9 are most frequently used. The three standard needle drivers shown are used for tagging each of the suspension sutures placed during the procedure. Labeling the drivers as shown aids in the identification of each suspension suture.

fascia. Dissection along the lateral orbital wall progresses inferiorly to the level of the lateral canthus. This completes the lateral dissection of the endoforehead procedure.

The paramedian incisions are then made as previously described and are carried down through the periosteum. Dissection in zones 2 and 3 can be performed with a blind sweeping technique, as long as the dissection remains in a subperiosteal plane. The endoscope is inserted during dissection in zone 4. In general, zone 4 begins about 3 cm from the superior orbital rims. Endoscopically assisted dissection should always be performed in zone 4. The initial dissection proceeds toward the lateral aspect of the superior orbital rim. Further dissection laterally toward the temporal line of fusion will allow connection of zones 1 and 4. The dissection then proceeds in a medial direction along the superior orbital rim. Cautious dissection in this area is mandatory. The authors have noted variations in the supraorbital nerve anatomy. Occasionally, an accessory branch of the supraorbital nerve can be identified as far as 2.5 cm superior and lateral to the supraorbital nerve proper. Every effort should be made to preserve any accessory nerve branch. After identification of the supraorbital nerve, dissection continues medially exposing the origins of the corrugator muscles. The supratrochlear nerve travels in the substance of the corrugator muscles, so careful elevation of the corrugators is required. Typically, three fascicles of the supratrochlear nerve are identified and preserved. Prior to resection of the corrugator muscle, the periosteum of the superior orbital rim is released with a curved elevator. The periosteum should be released from the zygomaticofrontal suture line laterally moving medially toward the glabella. In patients with heavy tissues, especially males, the periosteum is released by cutting it with endoscopic scissors. With the periosteum cut medially, the supratrochlear nerve and corrugator muscles are clearly delineated.

The corrugator muscle is extensively resected from its point of origin to just beyond the supraorbital nerve. Resection of the muscle is facilitated with the use of an endoscopic punch. The rounded tips of the endoscopic punch allow safe resection without injuring more superficial soft-tissue structures. An endoscopic scissor is then used to divide the periosteum deep into the procerus muscle. The procerus muscle is resected after being thoroughly exposed. Resection of the procerus muscle should proceed down to the level of the nasoglabellar angle. Again, this is facilitated with the use of the endoscopic punch.

Typically, the endoscopic midface lift is started at this point. Following the completion of the endoscopic midface procedure, the paramedian incisions are closed and the brow is repositioned. In addition, a suction drain is placed through a separate stab incision in the scalp, near one of the paramedian incisions. The tip of the drain is directed to the level of the glabella with an endoscopic punch or grasper. The drain is secured to the scalp with a heavy drain stitch. The paramedian incisions are closed in two layers. A blunt traction hook is used to elevate the scalp and to position the brow. When proper brow position is obtained, a small stab incision is made in the scalp, with a no. 11 scalpel, in the vertical axis of the central brow. A 1.1 mm drill bit with a 4 mm stop is inserted through the stab incision and a unicortical hole in the calvarium is drilled. A 1.5 mm titanium post (Synthes, Paoli, Pennsylvania) is then placed in the drill hole. In most cases, two paramedian posts (one on each side) are sufficient to maintain the proper brow position.

Endomidface Procedure

The endoscopic midface procedure begins with the temporal dissection in zone 1, as outline in the previous section. The temporal vein 2 (sentinel vein), temporal vein 3, and, the zygomatico-temporal nerves are preserved when possible. The dissection continues in an anterior and inferior direction remaining above the intermediate temporal fascia. This continues down to the level of the zygomatic arch. The zygomatic arch is entered 2 to 3 mm above the superior border of the arch. Division of the intermediate temporal fascia is required, thus exposing the periosteum of the zygomatic arch. The authors prefer elevation of the anterior two-thirds of the zygomatic arch periosteum because it enables greater lifting and redistribution of the midface soft tissues. The periosteum of the entire zygomatic arch is elevated when soft tissues lateral to the cheek need to be elevated. Surgeon comfort with the dissection over the zygomatic arch is associated with a significant learning curve. We have found that communication of the midface and temporal dissections is accelerated with pre-elevation of the zygomatic arch, or at least the superior border of the arch.

The midface dissection at this point continues through an intraoral (upper buccal sulcus) incision. The authors' preferred incision is perpendicular to the alveolar ridge (vertical) at the level of the first premolar. We find that the vertically oriented incision preserves the mucosal integrity at the alveolar ridge, allowing a rapid, watertight closure that is associated with fewer complications. Under direct visualization, the initial subperiosteal dissection of the maxilla and malar area is performed. The endoscope is used for the upper malar dissection. The use of the endoscope minimizes trauma to the midface structures caused by excessive traction. The endoscope is most useful during periosteal elevation along the lateral half of the zygoma body, its extension underneath the fascia of the masseter muscle, and the anterior two-thirds of the zygomatic arch. The upper (medial) portion of the masseter tendon is also elevated from the zygoma. Endoscopic visualization assists in the preservation of the zygomaticofacial nerve. Dissection continues along the inferior and lateral orbital rim and continues toward the superior border of the zygomatic arch. Skeletonization of the infraorbital nerve is not necessary under most circumstances. In fact, preservation of the periosteum surrounding the infraorbital nerve will limit traction-type injuries to the nerve bundle.

With the initial midface dissection now complete, the endoscope is returned to the temporal area. An assistant elevates the soft tissue of the midface, thus allowing the surgeon to safely connect the temporal and midface dissection pockets under endoscopic control. Gentle elevation during this step protects the frontal branch of the facial nerve from injury. With wide communication of the temporal and midface pockets, the endoscope is returned through the upper buccal sulcus incision.

The inferior orbital rim is dissected further by elevating the inferior arcus marginalis. A 4-0 PDS suture (Ethicon), introduced endoscopically, is used to imbricate the medial SOOF to the lateral aspect of the inferior arcus marginalis. It is extremely important to check eye globe mobility at this juncture with a forced duction test. Improper placement of this imbricating suture can trap or place traction upon the inferior oblique muscle, thus limiting globe mobility.

The lateral aspect of the SOOF is then grasped with a 3-0 PDS suture, providing the first of three suspension sutures. Both ends of this suture are then passed through the temporal incision, under endoscopic guidance. We find it helpful to tag the suture ends with a labeled needle driver (Fig. 8). This allows the surgeon to keep track of each suspension suture. The second suspension suture to be placed is the cheek imbrication, or "modiolus" suture. This suture is placed into the tenuous periosteal/fascia/fat of the inferior maxillary soft tissue near the upper buccal sulcus incision. Both ends of this suture are then directed through the temporal incision and tagged, as previously described.

Exposure of the Bichat's fat pad follows the placement of the first two suspension sutures. Bichat's fat pad is approached through the superomedial wall of the buccal space. The periosteum and buccinator muscle are spread with the use of a blunt dissector. This allows the Bichat's fat pad to herniate through maintaining an intact capsular fascia. The fat pad should be carefully dissected free from the wall of the buccal space. The Bichat's fat pad should be easily movable for repositioning as a pedicle flap. A 4-0 PDS suture is then woven into the fat

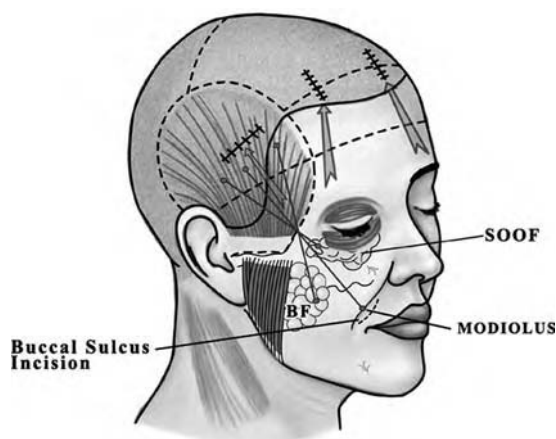


FIGURE 9 The blue lines above represent each of the suspension sutures placed during the endoscopic midface procedure. Note the independent vectors of pull each suture provides. The arrows indicate the direction of lifting created by closure of the temporal incisions and placement of the titanium posts in paramedian regions. *Abbreviation:* SOOF, suborbicular is oculi fat pad.

pad and the suture ends delivered to the temporal area, similar to the previously placed suspension sutures. The endoscope should be used to visualize the delivery of the pedicled fat flap over the zygomatic arch. The endoscope can also assess the trajectory of the suspensions sutures (Fig. 9). It is important to avoid criss-crossing the suspension sutures as they are passed temporally. Otherwise, asymmetric lifting will result when the sutures are allowed to twist around each other.

Each of the suspension sutures is then secured to the temporal fascia proper, in ordered fashion. The sutures should be placed in the temporal fascia proper, below the level of the temporal incision. The first suture, the Bichat's pad fat suspension, should be placed most medially. The inferior malar periosteum/fascia/fat or "modiolus" suture is placed next, in a more lateral location of the temporal fascia proper. The most lateral suture, the SOOF suture, is the last to be anchored to the temporal fascia proper. This completes the suspension of the midface.

Butterfly drains are placed bilaterally through separate stab incisions in the temporal scalp. Each drain is carefully directed into the midface and secured to the temporal scalp with a suture. The superficial temporal fascia is then anchored to the temporal fascia proper with two 4-0 PDS sutures, while an assistant provides superomedial traction to the advanced scalp. The intraoral incisions are then closed with interrupted 4-0 chromic cat gut sutures.

The versatility of this procedure can be seen in the following preoperative and postoperative views of patients treated at our facility, as shown in Figures 10–21. Restoration of facial volume results in a more youthful, rested appearance as shown in these patient examples.

(Text continues on page 333)



FIGURE 10 Preoperative (*left*) and postoperative (*right*) full-face views of a 46-year-old female who underwent an endoscopic forehead and midface rejuvenation. The postoperative photo was taken one year following the operative procedure. Note the improved brow position and softening of the nasolabial folds.



FIGURE 11 The three-quarter views of the patient shown in Figure 10 demonstrate the improved cheek fullness and elevation of the brow postoperatively (*right*). The contour of the brow and cheek (*right*) follows a more aesthetically pleasing “double ogee” or multicurvilinear line of beauty.



FIGURE 12 The lateral views of the patient from Figures 10 and 11 further show the improved brow position postoperatively (*right*). The patient has a more relaxed and youthful appearance.



FIGURE 13 Preoperative (*left*) and postoperative (*right*) full-face views of a 53-year-old female following a full endoscopic subperiosteal facelift. Patient follow-up approximately two years postoperatively (*right*) reveals restoration of her cheek bone prominence and lifting of the corners of the mouth accomplished with the suspension suture techniques described in the text.



FIGURE 14 The three-quarter views of the patient in Figure 13 highlight the restoration of upper cheek volume and loss of the heavy brow seen in the preoperative view (*left*).



FIGURE 15 The lateral views of the patient seen in Figures 13 and 14 demonstrate the softening of the marionette lines and enhanced definition to the malar area postoperatively (*right*).



FIGURE 16 The full-face views of this 45-year-old female demonstrate how the endoscopic rhytidectomy technique can soften deep forehead creases and create a more youthful cheek contour postoperatively (*right*). Mobilization of the Bichat's fat pad contributes to this more sculpted nature of the cheek region.



FIGURE 17 The dramatic contour improvement of the brow and upper cheek (the multicurvilinear line of beauty) that can be achieved with the full endoscopic facelift (*right*) is evident in the three-quarter view of the patient from Figure 16.



FIGURE 18 Lateral views of the patient seen in Figures 16 and 17 highlight the degree of cheek volume restoration that can be achieved with the endoscopic techniques (*right*).



FIGURE 19 The 59-year-old patient shown here demonstrates typical signs of advanced facial aging. Significant rhytid formation and soft tissue descent, and severe acne scarring are evident in this patient preoperatively (*left*). Softening of the deep rhytids and acne pitting resulted from a full endoscopic facelift preformed in conjunction with a full cervicofacial lift (*right*).



FIGURE 20 The degree of facial rejuvenation that can be accomplished with the endoscopic techniques is clearly evident from these three-quarter preoperative (*left*) and postoperative (*right*) views of the patient shown in Figure 19. Considerable restoration of a more youthful and rested appearance results.



FIGURE 21 The lateral views of the patient seen in Figures 19 and 20 highlight the softening of the deep rhytids and improved cheek contour.

Bichat's Fat Pad Excision

There is a subset of patients who present for facial rejuvenation that demonstrate a cherubic appearance. Characteristic features of this subset include chubby cheeks, significant bulk and pseudoherniation of Bichat's fat pad, and good malar bone support. Suspension of the fat pad in these patients will lead to an exaggeration of their cherubic features. Instead, these patients benefit from excision of Bichat's fat pad. Dissection of the fat pad proceeds as previously outlined. However, care must be taken during resection of the fat pad. Undue traction of the fat pad can result in injury to neurovascular structures and/or Stensen's duct. Meticulous hemostasis should be obtained and can be facilitated by the use of bipolar cautery during Bichat's fat pad excision.

Fat Grafting

Structural fat grafting as described by Coleman (15) provides an excellent means for treating residual facial asymmetries or contour irregularities. Deep residual creases, such as the nasolabial folds and marionette lines can be effectively treated with this technique. Fat grafting has become a routine component of our comprehensive facial rejuvenation technique. The fat grafts are typically harvested from the lower abdomen toward the end of the midface procedure. If the abdomen has a paucity of fat, grafts should be harvested from alternative locations. Alternative locations for graft harvest include the hips, medial thighs, or posteromedial knee region. Because fat grafts are placed in a subcutaneous plane, they can be safely placed in patients

undergoing concomitant subperiosteal rhytidectomy. We find this approach advantageous toward the final aesthetic outcome.

POSTOPERATIVE CARE

The patients are monitored for 23 hours and discharged home under the care of a well-informed relative or practical nurse. The butterfly drains are attached to vacuum tubes (red top phlebotomy tubes) and changed periodically during the next 48 hours. We find that evacuation of this fluid minimizes the amount of facial edema, postoperatively. Drain output of 10–20 mL should be expected, on average. Drain removal occurs typically on the second postoperative day. Antibiotics, started prior to surgery, are continued for five days, postoperatively. Steroids are not routinely given. Supportive taping of the forehead and midface begins at the end of the operative procedure and continues for approximately 7 to 10 days. The titanium forehead posts are removed between days 10 and 14.

COMPLICATIONS

Complications related to the endoscopic subperiosteal facelift procedures include nerve injury, hematoma, infection and alopecia and scarring. Nerve injury, perhaps the most devastating complication, is typically seen with excessive traction during endoscopic manipulation. In an effort to decrease traction-related nerve injury, we prefer to use a 4 mm endoscope and a blunt cobra-tip sleeve. Retraction is avoided when possible and slender retractors are implemented when necessary. Minaturized instruments for dissection and manipulation have also been employed. With implementation of these steps, neuropraxia of the frontal branch of the facial nerve occurred in 0.4% of patients. Neuropraxia of the zygomaticus branch of the facial nerve and the infraorbital nerve occurred in 0.2% and 0.4% of patients, respectively (16). No permanent injury to motor nerves has been seen to date.

Hematoma and infection can be minimized with meticulous operative technique and adequate irrigation of the subperiosteal pockets with antibiotic solution prior to closure. Hematoma has been seen in a single patient, on postoperative day 4. This late presentation occurred secondary to an acute hypertensive episode. The hematoma was drained and the patient recovered uneventfully. Infection has been seen in one patient undergoing an endoscopic facelift procedure. The patient complained of severe pain in the cheek, 10 days postoperatively. Fluctuance of the cheek mound and tenderness was noted. Incision and drainage of the collection resulted in resolution of the infection without further sequelae.

Alopecia and scarring can be significant using the open subperiosteal approach. Widening and depression of the bicoronal incision can be difficult to treat cosmetically. Alopecia is rarely seen following the endoscopic facelift procedure. Scarring is less problematic given the small incision size of the access ports. Adequate infiltration of local anesthetic, preoperatively, and the judicious use of electrocautery can prevent unnecessary alopecia.

SUMMARY

The subperiosteal rhytidectomy technique, as originally described by Tessier, has benefited from significant technologic advances in medicine. The endoscope now allows extensive subperiosteal undermining of facial soft tissue through minimal access incisions. The conspicuous scar of the bicoronal incision has been replaced with several small, easily camouflaged scalp incisions. Improved understanding of facial anatomy and the facial aging process now allow surgeons to reposition and remodel the soft-tissue envelope with excellent aesthetic results. Restoration of facial volume can be achieved with the subperiosteal techniques described and can be applied to the full spectrum of patients with lasting results.

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23 | Cleft Palate

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INTRODUCTION

Cleft palate deformities remain a significant functional problem for affected patients. The ramifications of a palatal cleft, whether or not associated with other facial clefts, can be disabling. Early diagnosis and repair allows for the development of intelligible speech and proper language skills. In developed nations, prompt attention is the norm. However, in less fortunate societies around the world, children may go for years, or even decades, without adequate care. This chapter will focus on the management of the cleft palate. A brief discussion of epidemiology, anatomy, and embryology will be included to complete the discussion of this important topic.

EPIDEMIOLOGY

Clefts of the palate are most often seen in conjunction with clefting of lip. The incidence of this combined defect is approximately 1:1000 in Caucasians, 0.4:1000 in Blacks, and 2:1000 in Asians (1–3). American Indians have the highest known incidence of palatal clefting at approximately 3.6:1000. Isolated clefting of the palate is a less frequent finding. The incidence is approximately 1:2000. It is seen more commonly in females and appears to be race nonspecific. Isolated clefts of the palate, however, are more frequently associated with other syndromes and abnormalities. Examples include the Pierre Robin sequence, velocardiofacial syndrome, Stickler's syndrome, and Van der Woude's syndrome.

ANATOMY

The palate is a complex structure composed of bone, muscle, and mucosa. It possesses both static and dynamic qualities, which are imperative for normal speech and feeding. An intact and properly functioning palate is a vital component of routine daily existence.

The palatine process of the maxillary bone is the foundation of the hard palate and forms the majority of this structure. The paired palatine bones also contribute to the hard palate, providing for a small segment of the posterior aspect. Three-paired foramina permeate these bones and transmit relevant blood vessels. The paired incisive foramina are located anteriorly and centrally just behind the central incisors. The paired greater and lesser palatine foramina are located posterolaterally. Through these posterior foramina emerge similarly named blood vessels, the greater and lesser palatine arteries, which are terminal branches of the internal maxillary artery. The greater palatine arteries subsequently traverse the hard palate in a posterior to anterior direction and reenter the hard palate at the incisive foramina. The origin and course of the greater palatine vessels are important to know since the mucoperiosteal flaps routinely elevated during cleft surgery are primarily based on them.

The posterior or soft palate is a dynamic structure composed of five paired muscles: the levator veli palatini, tensor veli palatini, palatoglossus, palatopharyngeus, and musculus uvulae. It is quite amazing how these distinct muscles are compressed into a minute area and at the same time manage to maintain independent function yet interact in a coordinated fashion. All neural innervation to the muscles of the soft palate is from the vagus nerve via the pharyngeal plexus, except for the tensor veli palatini muscle, which is innervated by the trigeminal nerve.

The levator veli palatini muscle is the most important of the palatal muscles. Normally, it forms a transverse sling across the midline of the soft palate. As its name implies, this muscle acts primarily as an elevator of the soft palate. It also has an attachment to the cartilaginous

eustachian tube and plays a partial role in normal eustachian tube function. In cleft palate patients, the normal transverse orientation of the muscle is disrupted. Instead the muscle fibers are oriented longitudinally and insert into the posterior aspect of the hard palate. Detachment of the muscle from the posterior palate and reorienting of its fibers to recreate the sling is crucial for palate surgery to be effective.

Although the tensor veli palatini muscle inserts into the soft palate, it has little to do with palatal function. Its main action has to do with opening of the eustachian tube and maintenance of middle ear drainage (4,5). Like the levator muscle, the tensor veli palatini also originates from the eustachian tube. Its tendon then hooks around the hamulus of the medial pterygoid plate. Clefting of the palate is associated with mal-orientation of the muscle and subluxation of its tendon off the hamulus. As a result, the majority of cleft palate patients have chronic eustachian tube dysfunction and requires placement of tympanostomy tubes through the tympanic membrane.

The palatoglossus, palatopharyngeus, and musculus uvulae muscles act synergistically to facilitate narrowing of the oropharynx with both speech and feeding. Clinically, the palatoglossus and palatopharyngeus muscles make up the anterior and posterior tonsil pillars, respectively. The palatopharyngeus muscle is of particular importance since it is basis for the sphincter pharyngoplasty procedure which is often used for cases of persistent velopharyngeal insufficiency (6,7).

EMBRYOLOGY

Embryologically, the palate is divided into two parts: the primary and secondary palate. The primary palate is composed of all palatal structures anterior to the incisive foramen. This includes the anterior maxillary bone (premaxilla) and all four incisor teeth. The secondary palate contains all structures from the incisive foramen to the uvula. This nomenclature and anatomy should be understood because identification and proper categorization of cleft deformities is important. Often times, people become confused and label the whole hard palate as the primary palate and the soft palate as the secondary palate. Although the hard palate is included in the primary palate, only the region anterior to the incisive foramen is part of the primary palate. In the same respect, although a cleft of the soft palate is in fact a cleft of the secondary palate, it is only a partial cleft of the secondary palate.

Development and growth of the palate begin around the fifth week of life (8,9). At that time, fusion in the midline of mesenchymal structures begins and sets the ground for the definitive palate. Anteriorly, the medial nasal prominences merge to form the median palatine process, which subsequently develops into the primary palate. Posteriorly, the lateral palatine processes fuse with the nasal septum in the midline and become the secondary palate. Closure or fusion of the palate proceeds in a sequential anterior to posterior fashion. The primary palate closes first, followed by the secondary palate. The development and closure of the primary palate will begin around the fifth week of life and approach completion by the eighth week. Subsequently, in a zipper-like fashion, the secondary palate forms and fuses in a posteriorly directed fashion. This process takes place from about the eighth to twelfth week of life. Complete palatal closure appears to be closely coordinated with descent of the tongue in the developing fetus. In cases where there is a failure of the tongue to properly descend out of the way of the approaching palatal shelves, clefting of the palate can be seen. Patients with the Pierre Robin deformity are prime examples of this type of disruption (10).

TIMING OF SURGERY

The primary goal of cleft palate surgery is to allow for the eventual development of functional and intelligible speech. Therefore, the timing of palatal surgery is specifically focused around this critical time period in a child's life. Feeding is a secondary issue in the realm of cleft palate repair since most affected children are able to compensate quite well and thrive despite the presence of a defect. Although an infant's sucking mechanism may be hindered by a clefted palate, its ability to swallow is usually normal. The goal, therefore, is to be able to get enough nutrition to the back of the child's throat so that its intact swallow function can carry the food

to the stomach. Feeding devices, such as compressible bottles and high flow nipples, have been shown to successfully deliver adequate amounts of milk or formula (11). In addition, several behavioral and positional modifications to feeding are felt to be helpful. These include frequent burping, upright positioning during feeding, and placement of the nipple toward the side of the mouth away from the cleft.

Most clefts of the palate are associated with clefting of the lip; therefore, a coordinated and timed effort is going to be made for the repair of these two defects. In general, our philosophy is that we would rather treat a palatal defect sooner than later. We try to treat the cleft lip at approximately three months of age, and aim for palatal repair at 8 to 10 months of age. We have found that 8 to 10 months is a good age range to intervene because at this age mouth size is quite large allowing for better surgical exposure and maneuverability. In addition, commencement of intelligible speech begins soon after this point. Operating earlier than eight months can at times be technically difficult causing undue frustration to the surgeon. Obviously, there are always exceptions to our age preference if other comorbidities exist which make proceeding with surgery dangerous. In the presence of the Pierre Robin sequence, we have delayed our palatal repair to at least 14 months of age.

In circumstances where clefting of the palate extends anteriorly to include the alveolar arch, repair of the alveolus is also required. If left untreated, a persistent oronasal fistula and potential loss of erupting teeth through the cleft are the end result. There are two schools of thought for managing the clefted alveolus. One school believes in treating the alveolar cleft early, either at the time of primary lip or palate repair or before the age of two (12–14). Another school, the one which we subscribe to, feels that alveolar bone grafting should be staged as a secondary procedure and completed at a later time when the child is older (15–17). Convincing arguments have been verbalized on both ends. Primary or early repair is believed to prevent collapse of the palatal segments; however, it has also been associated with detrimental effects such as maxillary hypoplasia and poor arch forms. A recent survey of 107 craniofacial centers across North America revealed that 93% of the centers were performing alveolar repair secondarily (18). We have found that closure of an alveolar cleft with bone graft between six and nine years is ideal. This age range precedes the eruption of the permanent dentition and coincides with the completion of transverse maxillary growth (19,20). In addition, iliac crest cancellous bone is abundant at these ages and is readily harvested as the graft material.

SURGICAL METHODS

The mainstay for treatment of cleft palate deformities is surgery. In addition to the reconstructive surgeon who will repair the cleft defect, a coordinated effort among different medical specialties is required. Appropriate care will include involvement of a plastic surgeon, otolaryngologist, pediatrician, geneticist, audiologist, speech pathologist, dentist/prosthodontist, social worker, and if necessary a child psychologist/psychiatrist. Without dedicated involvement from each and every one of these fields, a thorough work-up and treatment strategy cannot be achieved.

Over the years many different techniques for cleft palate reconstruction have been developed. Of these, four methods have stood the test of time and remain the most frequently used today. These include the von Langenbeck, Bardach two-flap, V-Y flap, and Furlow double opposing Z-plasty techniques. Each technique has inherent positive and negative qualities, which have been debated over the years; however, the ultimate choice of procedure will depend on the reconstructive surgeon's preference.

Whichever method of repair is chosen, the same basic principles of perioperative care still stand. General anesthesia is induced with an oroendotracheal tube. A preoperative blood cell count is routinely obtained. Blood loss is usually minimal during the surgery; however, we like to know our starting point in the event significant bleeding is encountered. To date, we have not needed to transfuse blood products for any of our cleft patients. Perioperative antibiotics are administered only for patients with predisposing cardiac valve conditions. In such cases, Clindamycin (10 mg/kg) is given prior to incision time and continued every eight hours for five days. Local anesthesia consisting of lidocaine with epinephrine is used for both analgesia and hemostasis. A Dingman mouth gag is used during the procedure for maximum intraoral exposure.

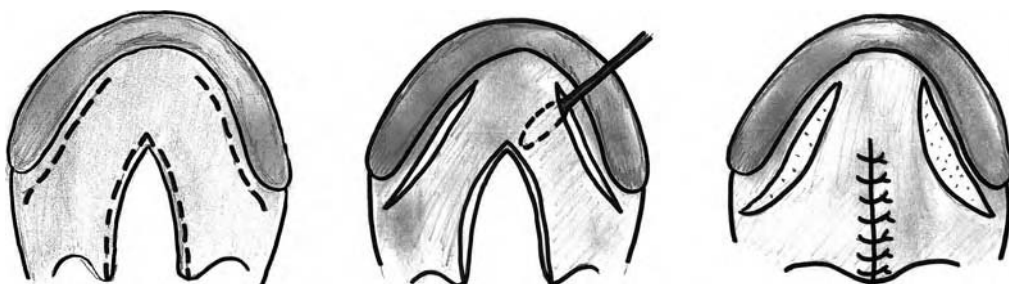


FIGURE 1 The von Langenbeck palatoplasty.

von Langenbeck Palatoplasty

In 1861, Bernhard von Langenbeck developed a method of cleft palate repair that involves the use of two bipedicle mucoperiosteal flaps (21). The relative simplicity of this technique has carried it through the years. Incisions are carried out around the edges of the cleft itself. Counter incisions are subsequently made at the inner border of the alveolus within the prominent rugae of the palate mucosa and continued around the posterior aspect of the maxillary tuberosities (Fig. 1). The extent of the counter incisions will depend on the size of the cleft. Elevation and advancement of the flaps toward the midline allow closure of the cleft. However, because the flaps remain attached anteriorly, dramatic posterior movement cannot be performed. As a result significant palatal lengthening cannot be achieved. In addition, large clefts of both the hard and soft palate may be difficult to close resulting in the potential for development of an oronasal fistula (22,23).

Bardach Two-Flap Palatoplasty

Janusz Bardach's two-flap palatoplasty is our procedure of choice for clefts of both the hard and soft palate (24). This technique utilizes two unipedicled flaps based on the greater palatine vessels (Fig. 2). Incisions are similar to the von Langenbeck technique; however, division of the anterior attachment is also carried out. This allows for some lengthening of the soft palate to be achieved (25). Extensive dissection and elevation of the flaps are performed with this procedure. Isolation of the flaps on their greater palatine vessels allows complete soft-tissue mobilization. Release of the levator muscle from the posterior aspect of the hard palate allows reorientation and creation of the levator sling. We can easily obtain a tension-free closure in the midline using this technique. Nasal mucosal flaps are also mobilized to allow a stable three-layer closure of the cleft defect. We use 5-0 Vicryl® suture for nasal mucosa, 4-0 Vicryl® for muscle approximation in the midline, and 4-0 Vicryl® suture for closure of the oral mucosa. Laterally, areas of exposed hard palate that are created using this technique rapidly remucosalize and heal well. We have not found the need to utilize buccal mucosal flaps to fill in these lateral defects.



FIGURE 2 The Bardach two-flap palatoplasty.

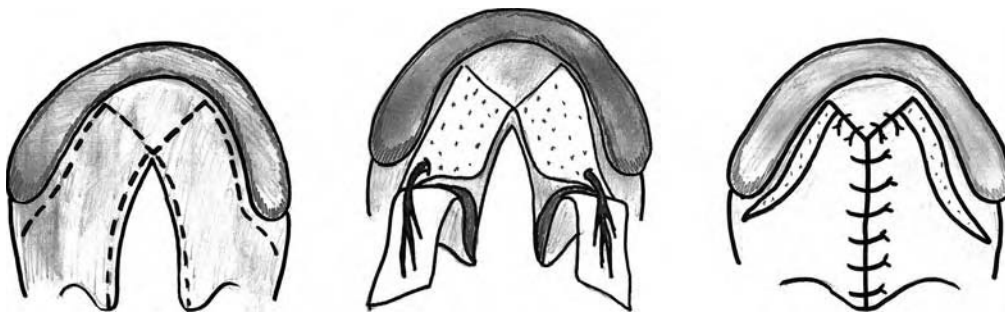


FIGURE 3 V-Y palatoplasty.

V-Y Pushback/Three-Flap Palatoplasty

This technique for palate repair is also named as the Wardill-Kilner-Veau technique (26). Its primary advantage is reported to be palatal lengthening. Three sets of flaps are created, one anteriorly over the primary palate, and two posterolaterally over the palatine shelves (Fig. 3). The two posterior flaps are advanced along the edge of the anterior flap during closure to achieve a lengthening effect. Incomplete clefts of the palate appear to be best suited for use with this technique. As with the previously mentioned procedures, elevation of nasal mucosa and oral mucoperiosteal flaps is completed along with release of the levator muscle from the posterior hard palate. Layered closure then follows. A major disadvantage to this repair method is an increased incidence of fistula formation when compared to the other techniques available (22,27).

Double Opposing Z-plasty Palatoplasty

The Furlow palatoplasty technique incorporates the lengthening effect of a Z-plasty into the closure of a cleft palate defect (25,28,29). In addition to adding length to the soft palate, the muscles of the palate, in particular the levator veli palatini, are reoriented to their natural position.

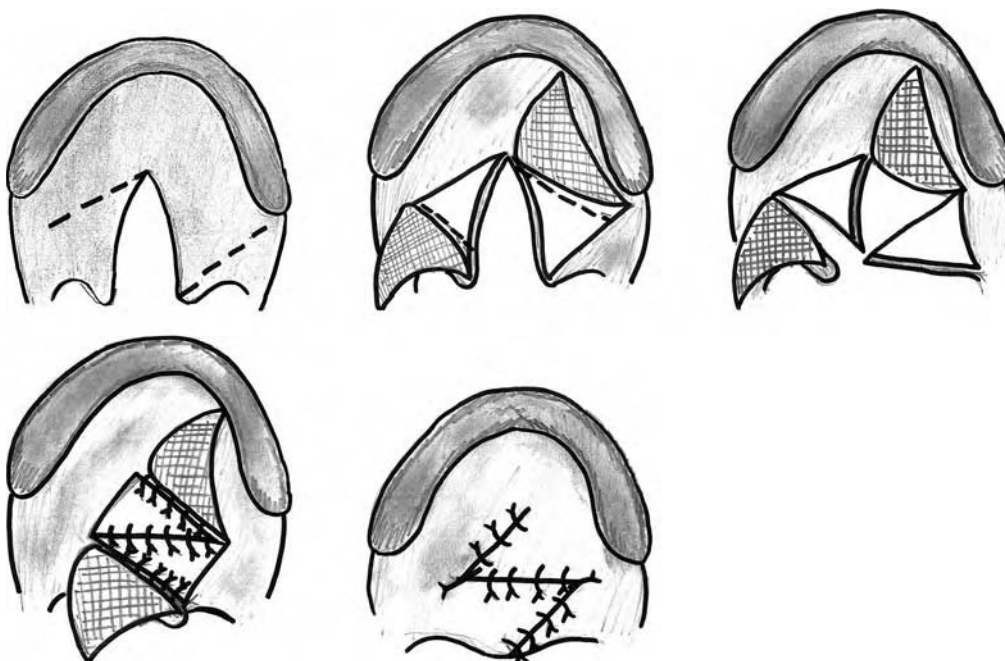


FIGURE 4 The Furlow palatoplasty.

These two qualities are the primary advantage for using this particular technique. Mirror image Z-plasties are created on both the oral and nasal mucosa sides (Fig. 4). The soft palate musculature is elevated with the flaps and reinset with a three-layer closure. We have found that this procedure achieves the best lengthening effect for the soft palate. Closure of extremely wide clefts or clefts of both the hard and soft palate can be problematic with this procedure. Fistula formation, particularly at the junction of the hard and soft palate is one of the more commonly encountered problems (22,30). Currently, clefts of the soft palate or submucous clefts appear to be the best candidates for the Furlow palatoplasty (31,32). We have also employed this technique successfully in patients with velopharyngeal insufficiency and small midline gaps (33).

POSTOPERATIVE CARE

Postoperatively, patients are admitted to a regular hospital floor for at least 24 hours for observation. Continuous pulse-oximetry is utilized. For syndromic patients or those with precarious airways, admission to a monitored unit may be indicated. Patients are immediately able to resume a clear liquid diet. Tylenol with codeine elixir is usually all that is necessary for pain control. Morphine sulfate supplementation can be used for break through pain. In the majority of cases, patients are tolerating adequate oral consumption and are discharged by postoperative day two. Progression to a full liquid diet after 72 hours is the norm, and soft diet consumption begins at postoperative day five. First follow-up visit is 7 to 10 days postoperatively. We routinely use elbow restraints ("No-No's") on all our pediatric patients to prevent unintended self-manipulation of the repair site. These are continued and sent home with the patient for a total of three weeks.

COMPLICATIONS

Often times the act of performing a surgery is the easy part and the true challenge lies in the appropriate management of the postoperative complications. With respect to palatoplasty, the main issues to be aware of postoperatively are airway compromise, bleeding, fistula formation, and persistent velopharyngeal insufficiency (27). Disruption of maxillary or midfacial growth following surgery is also a relevant issue. Wide flap dissection and denuding of bone is believed to cause growth disturbances in children (34). However, if corrective palatal surgery is not undertaken, the long-term effects of chronic nasopharyngeal insufficiency are sure to outway future facial growth disturbances. Infection is a fairly infrequent finding in palatoplasty patients. As mentioned above, we do not routinely treat patients with antibiotics in the perioperative period and have experienced no overt infections in the last 15 years of practice.

In the immediate postoperative period attention toward the airway and bleeding are the main concerns. As with any oral surgery, edema and excessive secretions can contribute to respiratory compromise. Prolonged retraction on the tongue with the mouth gag can also result in significant delayed swelling of the tongue, which can result in catastrophic consequences (35–37). Use of perioperative steroids is controversial but may help with decreasing some of the postoperative edema (38). In select patients, particularly those with the Pierre Robin Sequence deformity, placement of a tracheotomy tube may be warranted. Hemorrhage can also be alarming. Diligent attention to hemostasis in the operating room can help decrease the possibility of this complication, but does not always completely prevent it. Often times minor oozing will self-resolve and does not require a second visit to the operating room. Delayed hemorrhage at five to seven days postoperatively can also occur usually related to sloughing of eschar with subsequent exposure of underlying vessels. If a blood clot is visible at the time of initial examination, it is generally a good idea not to remove it in an uncontrolled environment such as the emergency room, because this will most likely expose the culprit vessel and result in active hemorrhage. It is important to always remain calm in these situations and remember that transport to the operating for definitive hemostasis is the most reliable option.

Delayed complications of concern are the result of partial failure of the cleft repair; these present in the form of fistula formation or persistent velopharyngeal insufficiency. While not life threatening to the patient, they can still have a significant functional impact. The incidence of fistula formation has been reported as high as 40% and is more frequently associated with

wider clefts (22,39). We have encountered a less than 1% fistula rate in our population. Fistulas tend to arise in areas of greatest tension, either at the junction of the primary and secondary palates or at the junction of the hard and soft palates. Attendance to the problem will depend on the size and location of the fistula. A small anterior lesion may often be asymptomatic and needs no further treatment. A dental prosthesis may also be used. Local flap closure of larger symptomatic defects, however, is often warranted (40–42).

Persistent velopharyngeal insufficiency occurs in 10% to 25 % of repaired cleft palate patients, irrespective of the method used to repair the defect (43,44). A detailed discussion of velopharyngeal insufficiency is beyond the scope of this chapter. However, it is important to mention that these patients should have close follow-up with their surgeon in addition to a speech pathologist and otolaryngologist. Accurate assessment of the velopharyngeal closure pattern will help dictate a surgical versus nonsurgical approach to the patient. Surgical intervention is warranted when speech therapy has failed. Surgical options include the sphincter pharyngoplasty, posterior pharyngeal flap, or Furlow palatoplasty.

SUMMARY

Correction of the cleft palate deformity is an involved process that requires dedication and devotion from a multitude of specialties. Such deformities have lifelong impacts on children. Surgical correction is only a small part of the reconstructive and rehabilitative puzzle. The surgical techniques discussed in this chapter have persisted through time with little variation. Although there always seems to be room for improvement, these various techniques have shown consistent reproducibility and reliability. With the advancements in molecular medicine soon to be upon us in the future, particularly in the area of tissue engineering and manipulation of the human genome, these invasive modalities may become a thing of the past. Until we reach that time, however, we must continue diligently with our current means to provide for the patients a result that will allow for normal function and interaction in society.

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24 Aplasia Cutis Congenita

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INTRODUCTION

Aplasia cutis congenita (ACC) denotes congenitally localized or widespread absence of skin (1,2). Multiple classification systems have been proposed (3) for this heterogeneous group of disorders, which is associated with various other anomalies. Frieden (4) developed a nine-category classification system to group distinct clinical subtypes of ACC. The criteria for distinction between the groups takes into account the location and pattern of skin absence, associated malformations, and the mode of inheritance (4). Characteristically, the defect is a midline solitary lesion that most commonly affects the scalp (86%) without associated anomalies. Sometimes, this defect of the integumentary system extends beyond the dermis to involve the underlying bony calvarium and dura, occurring in approximately 35% of the scalp defect cases (5). Although the true incidence is unknown, ACC is a rare condition believed to occur in about one in 3000 live births (6). Since Cordon's original article in 1767 (2), greater than 500 cases, have been reported. Cordon's article was the first to describe ACC of the extremities, followed in 1826 by Campbell who described defects involving the scalp (7).

ETIOLOGY

There is no uniform consensus as to the etiology of ACC. However, most authors do believe that the condition is multifactorial in origin (3,4). Some of the more popular theories involve intrauterine trauma, ingestion of teratogens during pregnancy, intrauterine infections, detached amniotic adhesences, compromised cutaneous vasculature, and a variety of genetic factors. Stephen et al. observed that in scalp ACC, the lesions are typically in close proximity to the scalp hair whorl (8). This whorl is believed to be the point of maximal tension that occurs during rapid brain growth between weeks 10 and 18 of gestation. Therefore, tension has been theorized to disrupt the growth of overlying skin during this period of development. Other authors believe that failure of closure of the neural tube may explain the occurrence of midline lesions while the failure of closure of embryonic fusion lines may explain lateral ACC lesions (2). More recently, a mechanism for overexpression of glucocorticoid (an anti-inflammatory compound and potent inhibitor of epidermal proliferation) receptor demonstrated altered skin development with striking clinical resemblance to ACC in transgenic mice (9).

EPIDEMIOLOGY

The inheritance pattern has been described chiefly as autosomal dominant; however, autosomal recessive and sporadic patterns have also been described (4). Of the cases reported, 25% have been familial in origin with 69% of these displaying autosomal dominant inheritance (5). No

preference for a particular race or sex has been universally accepted; however mention of increased frequency in first-born females has been described in scalp or skull defects (10).

CLINICAL FINDINGS

The diagnosis of ACC is clinical. Cutaneous findings are found in the scalp, trunk, or extremities. Other clinical findings such as associated malformations or chromosomal defects (3) have been described. By far, the most common type is membranous aplasia cutis, which occurs primarily on the scalp. Evaluation at birth often reveals an ovoid defect that may appear hairless, ulcerated, or as a thin, smooth wrinkled epithelial membranous covering (6). Rarely, the lesion may contain thick, clear fluid. These bullous lesions may spontaneously drain and reform to a more typical flatter physical appearance (3). Although the size and depth of the defect are variable, the lesions are typically solitary, small (0.5 to 2 cm) with 1 to 2 cm of depression (6). They are often described as having a “punched out” appearance. Scalp ACC are generally symmetric in configuration and located in the vertex or temporal region of the head (11). Ulcerated lesions typically heal by granulation with resultant scar formation or cicatricial alopecia. Even if the skull is involved, ulcers typically heal spontaneously within several months (1), generally evolving into a residual atrophic or less likely, a hypertrophic scar. Most underlying bony defects tend to resolve completely during early life (1).

Less commonly, irregular, large, or stellate scalp defects have been described along the midline of the scalp (3). These lesions are often associated with large underlying bony defects (Fig. 1) with hidden venous system abnormalities or arterial-venous malformations. Therefore, radiologic imaging before surgical intervention is strongly recommended (3).

Aplasia cutis may involve the limbs. Also areas of the trunk may have associated defects such as in omphalocele and gastroschisis. Limb lesions tend to be large, linear, or stellate erosions. They are usually bilateral and symmetric (3). Healing may be accompanied by contractures, especially in the areas around the joints (1). Bart's syndrome, a variant with irregular defects of the extremities and trunk with skin blistering, is now considered to be a form of epidermolysis bullosa (3).

PATHOLOGY

The transition zone between normal skin and lesions of cutis aplasia is one where dermal appendages such as hair follicles and sebaceous glands are underdeveloped and diminished in

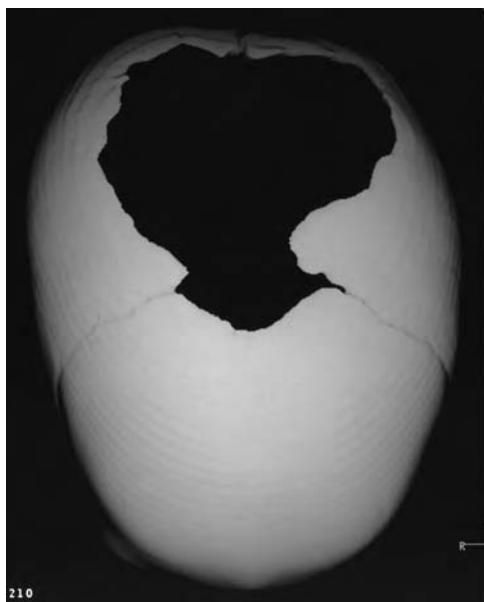


FIGURE 1 Clinical appearance of a large vertex skull defect in a 12-month-old child.

number and size. Within the actual defect, there are no blood vessels, dermal papillae, or elastic fibers. There is no associated inflammatory reaction. The corium layer is atrophic. The membrane, which covers the brain in deep defects, is made of a flattened layer of cuboidal nucleated cells (8,12).

DIFFERENTIAL DIAGNOSIS

Congenital scalp lesions warrant a thorough inspection at birth to exclude obstetrical trauma from forceps, fetal scalp probes, or congenital circumscribed hair loss. Other conditions that are included in the differential diagnosis are Goltz syndrome, incontinentia pigmenti, and epidermolysis bullosa. Goltz syndrome's (focal dermal hypoplasia) hallmark is thinning of the dermis rather than absence of the skin. Incontinentia pigmenti is clinically distinct with the presence of fat herniations of the skin and its unique linear configuration. Eosinophilic spongiosis is seen histologically. Epidermolysis bullosa is a disorder that encompasses phenotypically distinct groups characterized by induction of blisters after any mechanical trauma to the skin. Therefore, a careful history and comprehensive physical examination are mandatory.

COMPLICATIONS

There are a spectrum of complications associated with ACC ranging from life-threatening hemorrhage to excess sodium loss from the open defect, to wound infection and other sequelae associated with delayed wound healing (7). Lesions resting over the fontanel possess an increased risk of lethal hemorrhage. Kim et al. reported a similar case complicated by sagittal sinus hemorrhage. Meningitis is of particular concern with exposure of the underlying dura. Death has been reported in at least 20% of patients secondary to complications of hemorrhage, superior sagittal thrombosis, meningitis, and sepsis (13).

TREATMENT

Ideal management of patients with ACC remains controversial. Goals of therapy center around the prevention of eschar formation and its subsequent separation, facilitating skin coverage, and allowing for bony in-growth of new skull in cases of scalp ACC. The paradigm of therapy can be broken down into conservative and surgical treatments. The aim of conservative treatment is to allow granulation and eventual healing by secondary intention while avoiding eschar formation and desiccation. The use of saline dressings, continuous saline drips, betadine dressings, bacitracin ointment, and silver sulfadiazine dressings have been well documented (5,12). Betadine dressings are generally not favored because they lead to drying of the eschar with possible early separation and bleeding from the sagittal sinus. Bacitracin and silver sulfadiazine dressings have facilitated adequate closure of wounds (5) and provide antimicrobial activity. Saline dressings and drips, however, have no antibacterial properties and thus have only served as temporary measures while eventual surgical intervention is planned. Proponents of conservative therapy believe that Silvadene therapy provides antibiosis, allows for epithelialization and bony in-growth to occur, and prevents eschar desiccation and separation (5). Further, this mode of therapy prevents the neonate, who may have other congenital defects, from undergoing a major surgical procedure with general anesthesia. This avoids the infant from the associated operative anesthetic risks. The main complications encountered with conservative therapy are meningitis, wound sepsis, and potential hemorrhage from the sagittal sinus. Silvadene therapy appears to prevent these complications in most cases.

Operative therapy in ACC is multifaceted. Several surgical procedures have been described for both simple and complicated cases. Proponents of surgical intervention choose to promptly debride the eschar, in cases of scalp ACC, to reduce any risk to the dura. If the wound is infected, conservative therapy may be instituted with antimicrobial agents or even intravenous antibiotics until the field is suitable for eventual coverage. Small defects may be amenable to excision and primary closure. Split thickness skin grafting is an attractive option but poses some additional challenges. First, some authors have written in the past that bony in-growth has not been reported to occur following skin grafting (5). However, Smit et al. reported a case

of bone formation after skin grafting to a calvarial defect (14). Second, in order to proceed with definitive reconstruction, the skin graft must be peeled off of the brain or sagittal sinus. This aspect of the procedure has been associated with life-threatening hemorrhage. Additionally, this procedure may be limited by availability of donor sites and the challenges of handling fragile harvested skin. Scalp rotational flaps provide good coverage of these congenital defects and thus constitute a good surgical option. Bony in-growth beneath these flaps has been well documented (15). Problems that may be encountered include the defect may be too large for local flap coverage, the procedure carries the risk of significant blood loss, the integrity and vascularity of the surrounding skin may be less than optimal, and the procedure may be complicated by necrosis of the distal flaps. The use of fluorescein and other agents has been well described to test the viability of the flaps before rotation (12).

Several authors have used allografts for the temporary coverage of these defects (16). The use of allografts requires minimal surgical experience and these grafts are usually changed every few days to avoid rejection. These biomaterials allow for epithelialization to occur; therefore, bony in-growth is not hindered. Other authors have made use of acellular allogenic dermal grafts or cultured epithelial autografts for coverage (7). Proponents suggest that the dermal matrix of AlloDerm (an acellular dermal matrix, LifeCell Corp., Branchburg, NJ) is immunologically inert and provides a dermal base for cultured epithelial autografts and can limit eventual contracture. This leads to improved aesthetic and functional results.

After the initial phase of coverage, certain defects are too extensive or may be complicated by cerebral herniation and resulting signs and symptoms (i.e., seizures, hydrocephalus, CSF leaks). A more complicated approach for reconstruction involves split rib cranioplasty and free latissimus dorsi muscle flap (17). This and other microvascular-free tissue transfers should be used for very large defects or those severe cases with the potential for the above-mentioned complications, and in cases where conservative treatment and local flaps or grafts have been unsuccessful.

Another aspect of surgical therapy is how to manage the alopecic cicatrix that has resulted after successful soft-tissue coverage. McCray et al. presented a case report where scalp reduction was used successfully to excise a large scar on the vertex of the scalp of a 16-year-old boy (18). This seems to work well in cases where hair transplantation might fail because of the fibrous nature of the soft tissue. Others have used tissue expanders to achieve the same effect (17).

PREVENTION

A comprehensive family history is imperative. Specific questions should be directed to relatives with a seemingly unremarkable personal history of isolated areas of alopecia and/or limb abnormalities. Special attention should also be given to families with even a resolved isolated small scalp defect because reports have suggested that the progeny of such families have an increased risk of being born with more complex malformations (19). It is imperative that immediate, even remotely distant, family members be evaluated for subtle manifestations.

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25 | Mentoplasty

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INTRODUCTION

The shape and projection of the chin is an essential element of facial aesthetics and the single dominant feature in fashioning a facial profile. It provides the most protrusive component of the lower face that can impart positive characteristics to the individual when harmoniously positioned or less than endearing connotations when out of balance with the rest of the face. Its importance to a well-balanced face has been historically recognized in art and sculpture since the Greeks through Michelangelo to the present day.

The chin has been well described in both reconstructive and aesthetic facial surgery. It has a long history of surgical manipulation, mainly augmentative with the use of bone, cartilage, and synthetic implants dating back to over a half-century ago. More recent procedures have included bony reductions, advancement osteotomies, soft-tissue suspensions, and improved implant materials and shapes. Merging an appreciation of lower facial aesthetics with contemporary surgical techniques allows a large number of chin modifications to be done for every conceivable deformity.

CLINICAL ANATOMY

The soft tissue overlying the chin (*chin pad*) makes up half of its substance and is generally between 8 and 11 mm in thickness. It is usually thinner in the midline and thicker at the sides. The thickness of the chin pad can create three basic shapes: the thick pad, the thin pad, and the cleft chin (thin only in the center). Position, movement, and shape of the chin pad change during animation and are highly influenced by the underlying musculature (Fig. 1).

Despite the general thickness of the skin overlying the chin, the underlying muscular and bony anatomy is still well revealed. Of the eight muscles that comprise the labial and lingual aspects of the chin, the *mentalis muscle* is of prime importance. It is a paired muscle with a conical shape that starts off just below the mucosa of the mandibular sulcus and then sweeps downward and forward like two overlapping megaphones. The muscles almost always fuse with the center having the greatest confluence tapering out gradually. Its movement causes the chin pad to flatten and widen against the underlying bone (1,2).

An interesting component of the soft-tissue profile, which is highly influenced by the mentalis muscle, is the *labiomental fold* (LF). It represents the junction of the upper edge of the mentalis muscle and the lower edge of the orbicularis muscle. At this junction of the lip and chin, this depression is usually about 4 mm deep in women and 6 mm for men. Its vertical position between the lower lip and chin affects the perception of the shape of the chin. Ideally, it falls at the point located at the junction of the upper third with the lower two-thirds of the distance of the oral commissure to the chin (Fig. 1).

The osseous component of the chin includes the anterior portion of the mandibular body and *symphysis*. A small ridge is usually present at the symphyseal midline. The midline represents the greatest anteroposterior thickness, which may range from 10 to 15 mm. It is important to determine the horizontal and vertical contributions of the bony deformity and these may be classified in nine different categories: horizontal microgenia, horizontal macrogenia, vertical microgenia, vertical macrogenia, combined horizontal and vertical microgenia, combined horizontal and vertical macrogenia, vertical excess and horizontal deficiency (rare), vertical deficiency and horizontal excess, and asymmetries. The most forward position of the chin pad overlying the symphysis in lateral views is the *pogonion*. This landmark is often used as the sole

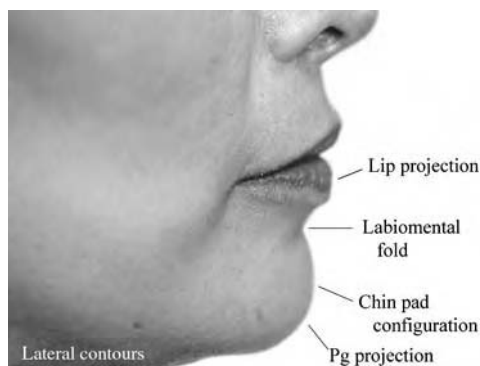


FIGURE 1 Important clinical landmarks of the chin region. Abbreviation: Pg, Pogonion.

criterion on which differing chin procedures are performed, which can result in aberrant clinical judgments (Fig. 1).

The mental *foramen* lies between the first and second premolars. Its vertical position of exit on the bone is quite variable in, somewhere between the middle of the bone to just above the inferior border of the mandible. The exit of the inferior alveolar nerve is not entirely horizontal; a anterior loop occurs before its exit (Fig. 2). The tooth root of greatest importance is the canine, being longer than any of the incisors or premolars. Its length averages around 25–27mm with its apices being at or below the mental foramen in most cases. Both the nerve exit and canine root apices are of great importance in numerous chin procedures.

PATIENT ASSESSMENT

Assessment of the chin can be simple and rapid, requiring only the surgeon's eyes, fingers, and the patient's smile. The important anatomy includes the size and shape of the *nose*, the degree of *lower lip eversion*, position of the *anterior teeth*, the configuration of the *chin pad* particularly during smiling, LF depth and height, and the width and anterior position of the *symphysis* (1).

The aesthetic relationship between the lip and nose and the teeter-tooter effect between the two is well recognized. While there is no exact mathematical method to determine the optimal nose–chin balance, one needs to develop an appreciation of their potential harmonious balance.

The anterior projection of the most prominent portion of the chin (pogonion) in the lateral view is the most recognized preoperative assessment. Proper projection is defined as a vertical line connecting the upper and lower lip which touches the pogonion or a vertical line from the nasion that also touches pogonion. This may be determined visually or by actual measurement on a lifesize photograph. Assessment of this feature alone, however, belies the complex interrelationship of the other lower facial structures.

On profile, the most anterior lower lip white roll should lie at the vertical position of pogonion. Significant lower lip eversion, however, may be indicative of a skeletal Class II deep bite with the lower teeth retropositioned and an anterior upper overjet. Lower lip eversion deepens the labiomentall fold and may be adversely affected with any type of chin enhancement.

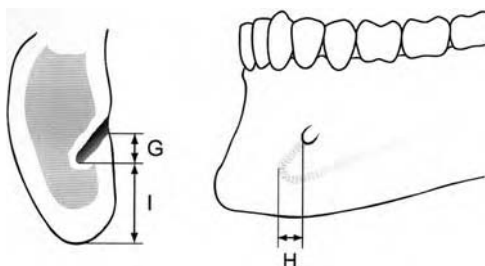


FIGURE 2 An appreciation of the anterior loop of the mental nerve, which occurs in most patients before the nerve exits the foramen.

The labiomental fold is the single most overlooked feature when considering chin alterations, yet it is one of the most important. Its height and depth provide each patient with a unique chin pad configuration and shape (Fig. 1). A high labiomental fold gives the chin a high pad percentage and vice versa (1). The outcomes of a chin implant in each of these cases can have dramatically different aesthetic results.

The thickness of the chin pad should be assessed in both static and dynamic (smiling) analyses. A static thick pad may become pulled down and ptotic with smiling. A thin pad can efface even dramatically, more fully revealing the underlying bony chin.

AESTHETIC CHIN CONCEPTS

Based on anatomy and an understanding of their interrelationships, the following are important aesthetic tenets about manipulations of the chin region:

1. Men will tolerate a larger chin than women.
2. Always undercorrect a woman's chin.
3. Bringing the chin forward, whether by osteotomy or implant, will make the chin look longer in most cases.
4. There are more effective options for advancing the chin than there are for reducing a prominent one. Soft-tissue redundancies are aesthetically displeasing and difficult to correct.
5. Significant lower lip eversion may be a sign of an underlying malocclusion, not just an isolated retrogenia.
6. A deep labiomental fold in retrogenia correction will make the chin pad appear postoperatively large when augmented.
7. A high labiomental fold (i.e., a high chin pad percentage) when augmented will produce a larger chin effect.
8. A cleft chin is a function of central mentalis muscle deficiency not a groove in the bone.
9. Liposuction should never be performed on the chin pad for reduction. Irreversible skin irregularities and adherent scarring will ensue.

ALLOPLASTIC MATERIALS

Indications, Advantages, and Disadvantages

Horizontal and combined horizontal-vertical microgenia are the main indications for alloplastic mentoplasty. Its principal advantage is its speed of execution, simplicity, rapid recovery, and minimal risk for permanent nerve paresthesia. Its main disadvantage is its limitations. An implant will only allow anteroposterior augmentation and minimal vertical change.

Materials

The use of implants for augmentation is, by far, the most common mentoplasty procedure performed. A wide variety of synthetic materials have been used in the chin but the standard over time continues to be solid silicone. It is well tolerated, flexible, easy to insert and remove, can be easily manufactured in an endless number of configurations and sizes, and is inexpensive. Its flexibility allows even large extended implants to be placed through small incisions. As of this writing, porous polyethylene (Medpor) is the lone alternative and good results can be achieved with its use although it is more expensive, requires greater intraoperative time and effort for fashioning and placement, and is more difficult to remove (3). There is no evidence to indicate that one alloplastic material is "biologically" superior over another.

Surgical Technique

The cutaneous *submental* incision is preferred. It offers a direct approach for positioning of the implant and prevents its cephalic positioning/migration (4). It also allows the execution of liposuction and submentoplasty procedures through the same incision which many of these patients may also benefit. While the intraoral approach is an alternative, it disrupts the mentalis muscle



FIGURE 3 Contemporary versus traditional chin implant designs.

(requiring resuspension) and is prone to cephalic migration of the implant unless it is secured by screws.

The submental incision is made several mm anterior to the existing submental fold through which subperiosteal placement of the implant is done. Fixation of the implant can be done by suturing it to the subperiosteal cuff at the midline of the inferior symphysis or a simple single midline screw if desired.

The contemporary varieties of chin implants differ primarily by offering greater lateral extension options that provide a smoother transition into the parasymphyseal and body regions (Fig. 3). This allows for the creation of increased width to the chin and improved blending into the lateral body of the mandible without irregular transition zones.

Complications

Infection is rare but the implant could be salvaged by antibiotics alone if it occurs in the early postoperative period. Thereafter, implant removal is usually required for resolution. Persistent (> 2 weeks) lower lip numbness that is not improving merits repositioning of the implant as it is likely impinging on the mental nerve.

BONY PROCEDURES

Indications, Advantages, and Disadvantages

An osteotomy of the symphysis, while more extensive surgery than an implant, is the most versatile of all available procedures available for chin deformities. Because it is a bony procedure that requires extra equipment, it is far less commonly performed than an implant, particularly in the middle-aged and older patient. Its true value lies in the ability to not only reposition the bone but the overlying soft tissue as well in a multitude of directions. It can be used in all types of chin deformities with the exception of a setback procedure. It is definitely more effective than implants in chin deformities which have vertical and asymmetrical components. In the very limited indications for reduction procedures, an osteotomy by burring with soft-tissue suspension is preferable over a direct setback osteotomy procedure.

Surgical Technique (Osteotomies)

Bony manipulation of the chin requires a sagittal reciprocating saw, a straight handpiece for drilling bone holes, metal fixation devices (1.5 or 2.0 mm), and a burr. There are several key elements in successfully performing chin osteotomies while minimizing potential morbidity. An intraoral approach is used with the initial mucosal incision placed halfway on the buccal mucosa between the vermilion and the vestibule. It is important to not make the mucosal incision too long (past the canines), this avoiding injury to several large anterior branches of the mental nerve (Fig. 4). After passing through the mucosa, a 90° turn is made to cut through the mentalis muscle directly to the bone. A generous cuff of mentalis and mucosa is left on the superior side near the teeth. Wide subperiosteal dissection is done identifying the exit of the mental nerves



FIGURE 4 Design of intraoral incision for osteotomies, avoiding superficial branches of the mental nerve.

bilaterally. Depending upon the horizontal and vertical angulation of the desired bone cut, a reciprocating saw is used to make bicortical cuts below the apices of the canine and up to 5 mm below the mental foramens. Once downfractured, a pedicled osseous bone flap has been developed based on the attachments of the anterior floor and hyoid musculature. The desired bony repositioning is secured by fixation of the bone in a wide variety of wiring and plating techniques. A simple but very secure fixation method is the use of a 2.0 mm titanium step-plate. Coming in various horizontal lengths that can be adjusted vertically by bending the plate, mid-line placement with four screws provides excellent stability (Fig. 5). It is extremely important to resuspend and attach the mentalis muscle to the superior cuff previously left, closing it in layers and eliminating dead space.

The versatility of the osteotomy procedure is that the downfractured chin segment may simply be brought forward, jump-grafted completely in front of the superior segment, brought forward and down (lengthened), shifted to any side, vertically lengthened or shortened, split in the middle for either expansion (transverse widening of the chin) or contraction (narrowing of the chin) (Fig. 6). The imagination and aesthetic sense of the surgeon permits almost every conceivable bony alteration.

One interesting question is how to manage the bone step or gap left after the downfractured chin segmented is repositioned and stabilized. For most cases, there is no need to graft the defect as it fills in on its own within the first postoperative year. In select cases, particularly asymmetries, a bone graft or alloplast material (e.g., hydroxyapatite block) may be considered if the defect is large and the graft contributes to stability of the segments.

Complications

Wound dehiscence, infection, and hematoma can occur but are very uncommon. A good multilayered muscle closure minimizes these concerns. Inadvertently transecting the apices of



FIGURE 5 Titanium step-plate fixation of osteotomy.

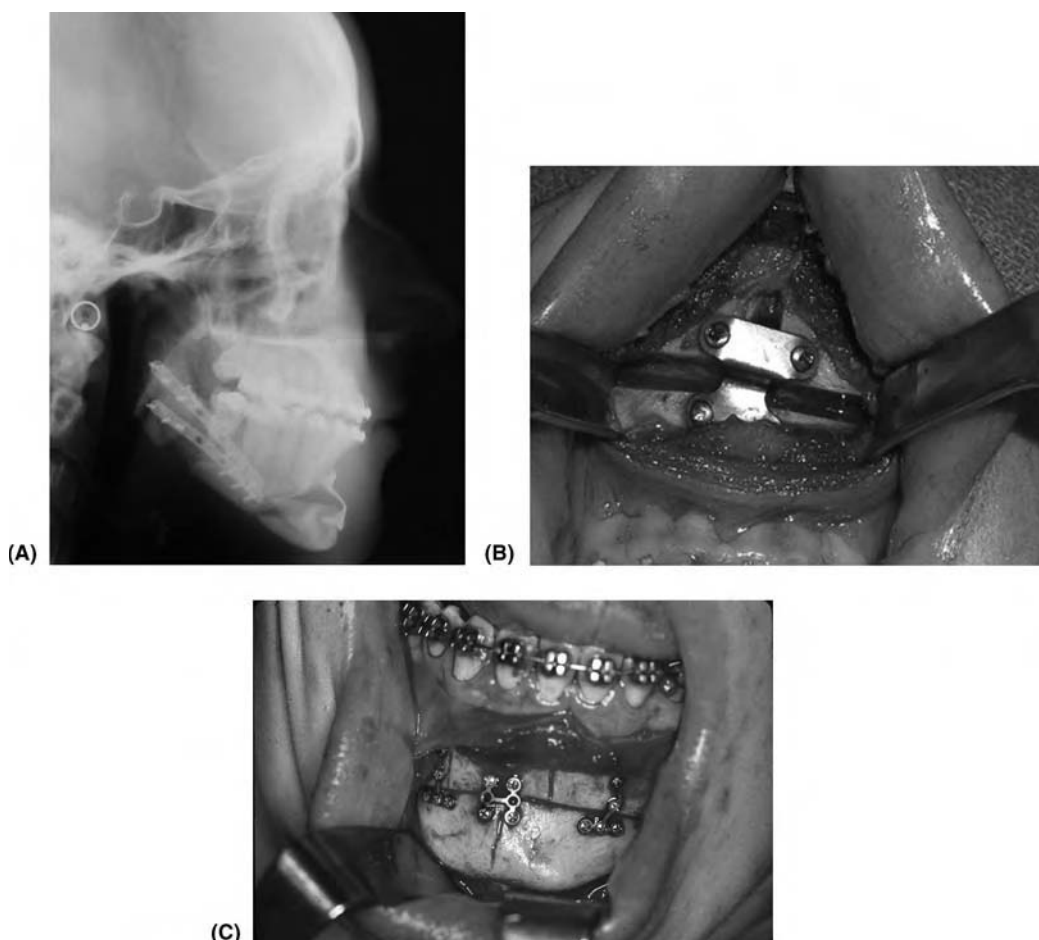


FIGURE 6 Osteotomy design and fixation options, (A) vertical lengthening with advancement, (B) advancement with width expansion, (C) osteotomy with lateral shift for asymmetry.

the canine is possible but is easily avoided by keeping the bone cut below the mental nerve. The apices of the incisors should be well above the bone cut. Make measurements off of a panorex if uncertain about root levels. Injury to branches of the mental nerve can occur just as easily from the vestibular incision as from the bone cut. Keep your intraoral vestibular incision no more lateral than the canine tooth. Keep your saw blade cut 5 mm below the mental foramen to avoid the anterior loop of the nerve. Soft-tissue (mentalis) ptosis can be avoided by proper resuspension of the muscle to the bone plate and the superior muscle cuff. Step-off deformities from the lateral wings of the downfractured segment can be avoided by checking their alignment to the inferior border after positioning and contouring with a burr if necessary.

Surgical Technique (Osteotomies)

Reduction of a large chin, although seemingly innocuous, is fraught with potential complications. Either an osteotomy with a setback or reduction by burring are two traditional treatment options. Each of these procedures can induce problems such as nerve injuries, bony irregularities, undesirable submental fullness, and chin pad ptosis. An effective compromise between these two procedures is a submental osteotomy with soft-tissue excision (5). Through a submental incision, the soft-tissue of the chin is degloved in a subperiosteal plane. A central osteotomy is performed with a burr of around 5–6 mm in the center, tapering out laterally. After osteotomy, some excision of the superior platysma muscle and the inferior mentalis muscle is

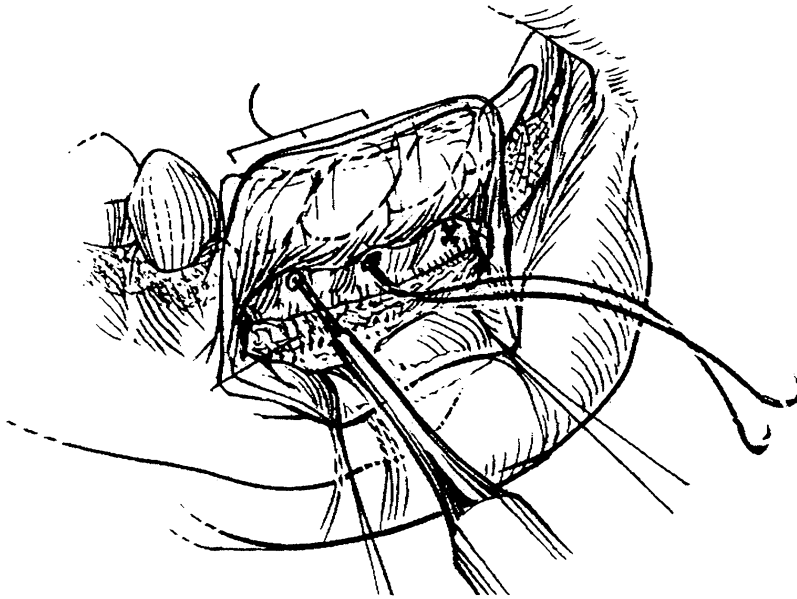


FIGURE 7 Submental osteotomy with submental soft-tissue excision for chin setback.

done to accommodate the relative excess of soft tissue after the bone reduction. The muscle and skin layers are then closed in layers. While this procedure leaves a flattened anterior chin point the potential for excessive submental tissue and chin pad ptosis can be avoided (Fig. 7).

Complications

Chin pad ptosis, skin irregularities, and potential inferior positioning of the lower lip can occur from any macrogenia reduction procedure including implant removal and burring reductions. If it occurs from implant removal, replacement with a smaller implant should be considered at the same time as removal of the first implant if possible. Once chin pad ptosis is present, it must be recognized that the fundamental problem is malposition of the mentalis muscle. In these cases, the *mentalis reefing* procedure is needed for correction (6,7). In this procedure, an intraoral vestibular incision and soft tissue release down to the menton is done. The residual contracted mentalis muscle is then elevated and sutured to bone holes placed through the upper, alveolus between the tooth roots or edentulous alveolar bone. This new attachment is most easily done with metal or resorbable suture anchors (Fig. 8). This suturing technique reattaches the mentalis muscle at a much higher origin and creates a more anatomic sulcus depth. With this soft-tissue resuspension, improved lower lip position and less incisor gingival show may also result.



FIGURE 8 Mentalis reefing procedure requiring superior fixation at the alveolar level using resorbable suture anchors.

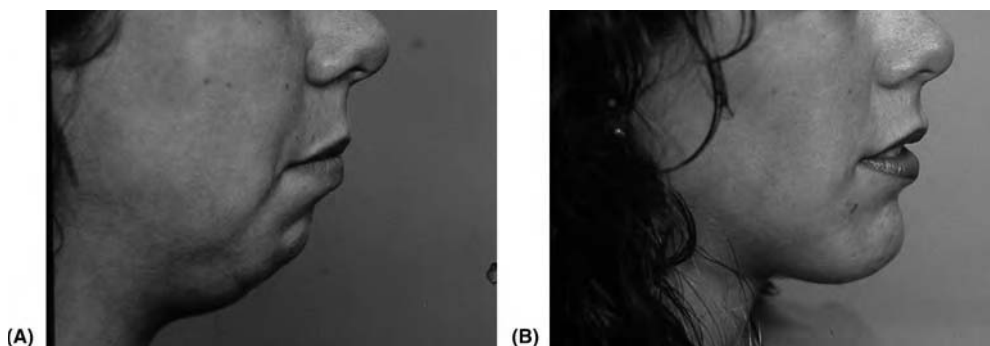


FIGURE 9 The possibilities of chin manipulation, (A) preoperatively and (B) 10 mm advancement osteotomy with submental liposuction.

SUMMARY

Aesthetic manipulation of the lower face should be perceived as more than simple sagittal augmentation of the chin. While a chin implant may often be all that is needed, an appreciation of the intricacies of the overlying soft-tissue anatomy and landmarks opens up an array of potential bone and muscle modifications as well. All of these chin procedures can be easily learned and safely executed with minimal morbidity while producing an array of subtle to striking facial changes (Fig. 9).

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26 Facial Paralysis

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INTRODUCTION

Facial paralysis produces significant functional, aesthetic, and emotional problems. Craniofacial surgeons may find the management of facial paralysis confusing, partly because of the myriad of surgical options presented in the literature. The use of an algorithmic approach in facial paralysis allows the surgeon to evaluate patients in a systematic fashion, thereby facilitating treatment planning. The use of treatment algorithms in facial paralysis is neither new (1,2,3,4,5), nor intended to replace thoughtful consideration of the many options in restoring function to the paralyzed face; rather, it is intended to guide the physician to an optimized treatment plan. Despite decades of advancement, there remains room for improvement in the treatment of these patients. Better muscle transfer techniques, adjunctive measures to enhance reinnervation, clinical outcome measures, and tissue engineering alternatives will all play a role in improving the care of these unfortunate patients.

ANATOMY

Facial Nerves

Motor fibers to the muscles of facial expression (plus the stylohyoid, posterior belly of the digastric muscle, and the stapedius) comprise the majority of axons contained within the facial nerve. The remaining fibers of the facial nerve include visceral motor fibers (salivo- and lacrimomotor function), general sensory fibers (to the external auditory canal), and special sensory fibers (taste fibers via the chorda tympani). Impulses from the motor cortex are projected through the internal capsule into the seventh cranial nerve nucleus. Input to the frontal branch portion of the facial nucleus is bilateral, while impulses to other muscles of facial expression decussate to the contralateral facial nucleus. This arrangement is the basis for the clinical finding of ipsilateral sparing of brow elevation in cases of central unilateral facial paralysis. Fibers then exit the pons and enter the temporal bone, where the nerve is vulnerable to both shear stresses and compressive neuropathies. The internal topography of the facial nerve at this level is variable. Upon exiting the temporal bone at the stylomastoid foramen, the nerve then passes between the superficial and deep lobes of the parotid gland. The nerve then divides into two main trunks, which then further divide within the parotid gland to form divisions. Traditionally, it is taught that this results in five divisions of the facial nerve; frontotemporal, zygomatic, buccal, marginal mandibular, and cervical. In practice, however, there is no distinct separation between the zygomatic and buccal branches either in their location or in the muscles they innervate. We prefer to use the term *Zygomaticobuccal* branches.

At their exit from the parotid gland, the facial nerve branches lie approximately 10 mm from the skin surface. They become progressively more superficial medially. The temporal branch may be only a few millimeters deep to the surface 5 cm distal to the parotid gland. Upon leaving the parotid gland, the facial nerve may have 8 to 15 branches. Distally, there is further arborization and interconnection of the branches, resulting in significant functional overlap; a single zygomaticobuccal branch may innervate the orbicularis oculi as well as the orbicularis oris.

The three or four branches of the temporal division run obliquely along the undersurface of the temporoparietal fascia after crossing the zygomatic arch 3–5 cm from the lateral orbital margin. They are most susceptible to injury along the lateral border of the frontalis muscle, where there is little adipose tissue and the nerves are virtually subcutaneous. These nerves innervate the frontalis and the upper orbicularis oculi muscles.

The zygomaticobuccal division consists of five to eight branches with significant innervation overlap such that one or two branches may be divided without causing weakness. These nerves innervate the lip elevators and the lower orbicularis oculi muscles, as well as the orbicularis oris and buccinator. It is the branches to the zygomaticus major and minor and the levators that are so crucial in microsurgical facial paralysis reconstruction.

The marginal mandibular division consists of one to three branches whose course begins up to 2 cm below the ramus of the mandible, crossing the mandible halfway between the angle and the symphysis. These branches lie on the deep surface of the platysma and cross superficial to the facial vessels approximately 3.5 cm from the edge of the parotid, innervating the depressor anguli oris, depressor labii inferioris, the mentalis muscle, and sometimes the upper platysma and superior orbicularis oris.

The cervical division consists of one branch that leaves the parotid below the angle of the mandible and runs on the deep surface of the platysma, entering it at the junction of the superior and middle thirds.

Facial Muscles

The facial muscles can largely be thought of as either sphincter dilators or constrictors. They consist of 17 paired muscles and one unpaired muscle, the orbicularis oris. The functions of the frontalis, orbicularis oculi, zygomaticus major, levator labii superioris, orbicularis oris, and depressor labii inferioris are the most clinically significant.

The frontalis muscle is a bilateral broad muscle 5–6 cm in width and 1 mm thick. It originates from the galea aponeurotica, inserting onto the superciliary ridge of the frontal bone and into fibers of the orbicularis oculi, procerus, and corrugator supercilii, as well as the overlying skin. It acts to dynamically elevate the brow and prevents brow ptosis with its resting tone.

The orbicularis oculi muscle constricts the sphincter of the eyelids. It is a continuous sheet of muscle with pretarsal (covering the tarsus), preseptal (covering the septum), and orbital (covering the orbital margin) components. In the lower eyelid, the orbital portion overlies the origins of the zygomaticus major, levator labii superioris, levator labii superioris alaeque nasi, and part of the masseter. Multiple motor nerve branches enter the muscle just medial to its lateral edge.

The zygomaticus major originates from the lower lateral portion of the body of the zygoma, with the orbicularis oculi and the zygomaticus minor covering the upper part. The zygomaticus major lies along a line from the helical root to the oral commissure, where it inserts into the modiolus (the point of insertion of the zygomaticus major and minor, orbicularis oris, buccinator, risorius, levator anguli oris, and depressor anguli oris). The nerve fibers enter the deep surface of the muscle (as is the case with all the muscles of facial expression except for the levator anguli oris, buccinator, and mentalis, which are innervated from their superficial surfaces). The lower lip depressors consist of the depressor labii inferioris and the depressor anguli oris. The platysma, through its insertions into the other lower lip depressors and the modiolus, is also a lower lip depressor.

FUNCTIONAL AND AESTHETIC PROBLEMS IN FACIAL PARALYSIS: PATIENT EVALUATION

It is important to take a careful history in order to establish the etiology. Facial paralysis can be congenital or acquired. In acquired cases, such as infectious or idiopathic facial paralysis, some recovery of function occurs, and it is important to establish that recovery has plateaued prior to surgical management in most cases.

Priorities in initial management include corneal protection, determination of etiology, detailed clinical assessment, and specific treatment directed toward the primary pathology.

Additional treatment is then carried out, addressing the specific deficits of function and cosmesis. Initial priorities can be divided into those that are “urgent” and those that are “not-so-urgent”.

“Urgent” Priorities: Corneal Protection

In the acute setting, protection of the eye should receive “urgent” priority six. Exposure keratitis results from incomplete eyelid closure (lagophthalmos) and lower lid paralytic ectropion. It may be exacerbated by decreased tear production, and absence of rolling up and out of the cornea with efforts to close the eyelids (known as Bell’s phenomenon). Acute protection is achieved with saline eyedrops during the day and ointments at night with lid taping. Voluntary eye closure should be performed when the eye feels irritated. A moisture chamber should be worn over the involved eye when outdoors or if the eye becomes irritated. Such nonoperative measures are often all that is necessary to prevent keratitis, especially in cases of transient or incomplete facial paralysis.

“Not-So-Urgent” Priorities: Examination and Diagnosis

“Not-so-urgent” priorities in initial management of facial paralysis include performing a thorough clinical assessment and establishing a diagnosis. When possible, preserving innervation of functioning muscles should be considered a priority, since skeletal muscle loses function dramatically with increasing denervation time.

The etiology of the facial nerve palsy must be determined in order to provide a prognosis. The treatment plan for a patient whose facial nerve palsy is expected to be transient will be markedly different from one whose deficits are expected to be permanent. Slow progression beyond three weeks is usually diagnostic of a tumor, while acute onset facial paralysis is characteristic of idiopathic (Bell’s) palsy, external blunt trauma, and surgical trauma to the facial nerve. With patients with incomplete paralysis, 95% to 99% recover completely with no sequelae. However, if the paresis progresses to total paralysis, the likelihood of satisfactory recovery drops to 75%.

A physical examination should be completed in an effort to localize the lesion. The intra-temporal branches of the facial nerve (the greater superficial petrosal nerve, the nerve to the stapedius, and the chorda tympani) should be assessed. The greater superficial petrosal nerve controls lacrimation, and its integrity can be tested with the Schirmer test. Usually performed by ophthalmologists, the Schirmer test is considered abnormal when a strip of filter paper placed in the fornix produces less than 5 mm of wetting at five minutes. An audiogram should be obtained in order to evaluate the function of the branch to the stapedius muscle. If the audiogram is abnormal, an MRI should be considered, especially if the paralysis is of slow onset, in order to rule out the presence of a mass. The chorda tympani can be tested using salty solutions placed on the tongue. A detailed examination of facial motion should be carried out in a systematic fashion. It is helpful to work from top down. The problems encountered in facial paralysis can be divided into three anatomic regions, consisting of the brow, eye, and lower face.

Brow position is evaluated in repose and with motion. The presence of forehead wrinkles is noted. The effects of brow (frontal branch) paralysis are more pronounced in older patients. The sagging brow produces a cosmetic asymmetry that can also obstruct superior field vision in a manner similar to dermatochalasis of the upper lid. The depressed brow conveys a serious or sad look. In an attempt to counteract sagging of the ipsilateral brow, the patient may unconsciously hyperelevate the contralateral brow, aggravating the height discrepancy.

Eyelid closure is evaluated both in repose and with attempted closure. Paralysis of the orbicularis oculi muscle can produce significant functional problems. While children seem to be able to adapt fairly well in most cases of congenital paralysis, adults are more susceptible to corneal exposure. Without the ability to effectively blink, tears are not effectively spread over the corneal surface. Eyelid closure depends on this muscle, which also produces a pumping action on the lacrimal sac, controlling the drainage of tears from the corneal surface into the lacrimal drainage system. Corneal exposure can lead to reflex tearing, resulting in excess tear production that is unable to be cleared through the lacrimal system. Thus, these patients can present with excess tearing (epiphora), the cause of which is actually a dry eye.

Paralysis of the orbicularis oculi muscle can also produce significant aesthetic problems. During smiling the vertical height of the palpebral fissure normally narrows. With facial paralysis the aperture height remains unchanged, leading to an inability to convey emotions. A flaccid orbicularis oculi also produces a paralytic ectropion of the lower lid. Eventually, especially in older patients, the ectropion will lead to scleral show, exacerbating corneal exposure. In children with congenital facial paralysis, scleral show caused by paralytic ectropion is usually not a major issue.

Dynamic and static midfacial motion, especially full-dental smiling, is noted, with particular attention to synkinesis and lip depressor activity. A patient may be described as having a *complete* paralysis, in which there is no CN VII motor function present, or a *partial* paralysis, where some motor function remains. The five individual motor branches can be described as having *complete* or *incomplete* paralysis as well.

Paralysis of the lip elevators and the lower face produces significant aesthetic problems. The inability to smile is perhaps the foremost concern of patients and families affected by facial paralysis. In unilateral cases, the asymmetry can be truly disfiguring, and is accentuated on animation. In bilateral cases, which are nearly always congenital, this inability to express emotion alone has resulted in children being treated as if they had learning disabilities or developmental delay. Lower lip depressor paralysis produces an asymmetric amount of lower dental show on smiling, and also interferes with the ability to frown.

Paralysis of the muscles of the lower face can result in functional problems too. Lack of nasal dilatory function can lead to or exacerbate nasal obstruction on the affected side. Difficulty in chewing on the affected side leads to drooling and cheek biting on the paralyzed side. Lack of orbicularis oris tone results in difficulty producing plosive sounds such as “b” and “p.” The drooling, which is worse with drinking, is socially embarrassing. This problem, along with the others mentioned above, can lead to patients intentionally avoiding social situations, producing withdrawal.

In addition to the physical examination, electrodiagnostic studies may be obtained to further localize the lesion and estimate the potential for recovery if there is a question of the diagnosis. Once diagnosis is completed, therapy should be directed toward the primary pathology if possible. If the prognosis for spontaneous recovery is poor, then surgical interventions should be considered.

MANAGEMENT

In general, if the facial muscles are intact and potentially can function, the surgeon will need to perform “nerve operations,” consisting of nerve repairs or transfers. Conversely, if the facial muscles are not available, then “muscle operations,” such as muscle transfers (6) or slings, are indicated.

If the Ipsilateral Facial Nerve is Available and the Facial Muscles are Available

Etiology

Both the facial nerve and muscles may be available in cases of peripheral facial paralysis caused by acute disruption of the extratemporal facial nerve (Fig. 1). For example, this type of lesion could be caused by resection of part of the facial nerve during parotidectomy, iatrogenic injury during a facelift, or as a result of a laceration or gunshot wound.

Treatment: Nerve Repair and Grafting

If the facial muscles are available (i.e., they are not impaired due to congenital deformity, trauma, or atrophy), then they can be potentially reinnervated. Every effort should be made to preserve the native facial muscles since their inherent potential function is vastly superior to any of the other options currently available (7). If the ipsilateral facial nerve is available but damaged, nerve repair or nerve grafting should be performed. The two basic principles of nerve repair apply. First, the repair must be made without significant tension. Second, the endoneurial surfaces of each end must be precisely coapted. If there is significant tension on

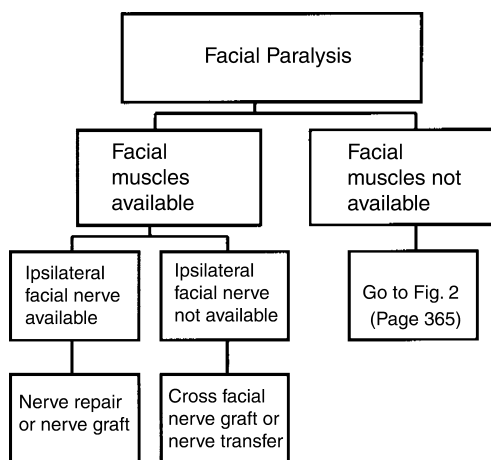


FIGURE 1 Algorithm for evaluation and treatment of facial paralysis—part 1.

the repair, a nerve graft must be performed. Even if a technically perfect nerve coaptation is performed, synkinesis, or *en masse* facial movement remains a common and troubling outcome. With nerve grafting, the problem is compounded because there are two sites of potential mismatch of nerve fibers and two regions of inflammation and fibrosis that the axonal growth cone must traverse.

When a nerve graft is required, the best conduit for axonal regeneration is fresh autologous donor nerve graft. From a practical standpoint, this is often best achieved with sural nerve grafts, but other potential donors include the great auricular, supraclavicular, medial antebrachial cutaneous, and lateral femoral cutaneous nerves (8,9). The choice of donor nerve depends on the length and axon volume needed to match the length deficit and the thickness of the native nerve. Tissue engineering may provide future alternatives to autologous donor nerve grafting (10).

Single Branch (Partial) Paralysis

If a single branch is injured, but other branches retain function, then the palsy is said to be *partial*. In certain cases, such as iatrogenic injury to the temporal branch during facelift procedures, the distal stump may not be present or able to be located. If the distal stump is not present, then reinnervation by nerve coaptation or nerve grafting is not possible. In such cases the patient is usually best treated as if the facial nerve and frontalis muscle are not available (see next section). However, “direct” neurotization, in which a proximal nerve stump is implanted directly into a denervated muscle belly, has been reported, and may have clinical application (11,12).

If the Ipsilateral Facial Nerve is not Available and the Facial Muscles are Available

Etiology

The ipsilateral facial nerve may be absent secondary to postsurgical, traumatic, or other causes (Fig. 1). Resection of a brainstem tumor such as an acoustic neuroma (vestibular schwannoma) may result in sacrifice of the facial nerve within or proximal to the temporal bone. Trauma involving the temporal bone may produce complete paralysis of the facial nerve if it is transected or crushed. Severe Bell’s palsy or infectious facial paralysis can result in near-total loss of clinical facial nerve function, yet the actual muscles remain present. In these situations, axons from sources other than the facial nerve must then be directed into the muscles in order to preserve muscle contractility. Again, if at all possible, the function of the native facial muscles should be preserved, since their motion is superior to those produced by any other reconstructive option.

Treatment

If the ipsilateral proximal stump of the facial nerve is not available for repair or grafting, then other sources should be sought for innervation of potentially functional facial muscles. In this situation, options for reinnervation include the contralateral facial nerve or other locally available nerves such as the trigeminal, spinal accessory, or hypoglossal nerves. The “babysitter” technique may also be used to preserve muscle function while a cross-facial nerve graft becomes repopulated with axons. These procedures are applicable when the facial muscles are still able to function with restored innervation (ideally within a year of injury). Use of the contralateral facial nerve with a cross-facial nerve graft has the potential advantage of allowing the patient to more readily produce spontaneous (mimetic) facial movements in response to emotions. Facial movements have the potential to be more natural than with the use of the hypoglossal nerve, which produces more mass movement.

Hypoglossal Nerve and the “Babysitter” Principle

The hypoglossal nerve can be used as a nerve donor in two ways; either all, or some of, the axons of the hypoglossal nerve may be directed to the facial nerve. In the former case, the hypoglossal nerve is completely transected and the proximal stump is coapted end-to-end to the distal facial nerve stump. This is the classic XII–VII anastomosis. In the latter, a nerve graft (“jump graft”) is used in an end-to-side manner (13,14), coapting the partially transected side of the hypoglossal nerve to a nerve graft, which is coapted end-to-end to the facial nerve. Alternatively, the facial nerve can sometimes be dissected into the temporal bone, thus freeing enough length to avoid the need for a nerve graft (15). The major advantage of the use of part of the axons from the hypoglossal nerve is that hemitongue function is well-preserved and mass motion is reduced (16,17).

The “babysitter” technique can be a useful adjunct to surgical rehabilitative strategies (18,19). Using this principle, temporary innervation of paralyzed facial muscles is supplied by motor axons from a non-VII source (such as the hypoglossal nerve), thus directing motion-specific axons to the target muscles. The advantage is that end organ, that is, muscle function can be preserved during procedures with a long latency period, such as cross-facial nerve grafting. Some have advocated primary use of a partial XII–VII end to side nerve transfer with a concomitant cross facial nerve graft in order to produce motion as early as possible, while maintaining tongue function (15).

Cross-Facial Nerve Grafting

Cross-facial nerve grafts with coaptation to the facial nerve branches on both sides, that is, VII–graft–VII have been used for over 30 years (20–22). This technique has the theoretical advantage of providing spontaneous function during facial motion. Cross-facial nerve grafting generally should not be employed as a primary procedure, but rather should be used to power a free muscle transfer as will be described later or to augment other procedures that are performed to restore facial nerve function. Currently, cross-facial nerve grafts are best used as an adjunct to other treatments that address resting tone and protection of the eye. The main disadvantage is that much of the “firepower” of the nerve is lost as axons drop off over the course of traversing the relatively long grafts needed and in crossing two neural coaptations often resulting in disappointingly weak facial motion. For this reason, many surgeons have turned to hypoglossal nerve transfers.

If Facial Muscles Are Not Available

Etiology

In cases of congenital facial nerve palsy, the facial muscles may be absent or unusable (Fig. 2). Likewise, in cases of established, longstanding facial paralysis, the facial muscles may have atrophied to the extent that they are no longer able to function even with restored innervation. We present a regional algorithm for patients in whom facial muscles are unavailable.

For the purposes of this discussion, the face can be divided into three regions: the brow/upper face, the eyelids, and the lower face. The techniques and objectives of surgical facial rehabilitation are different for each region. Again, many techniques have been reported to address

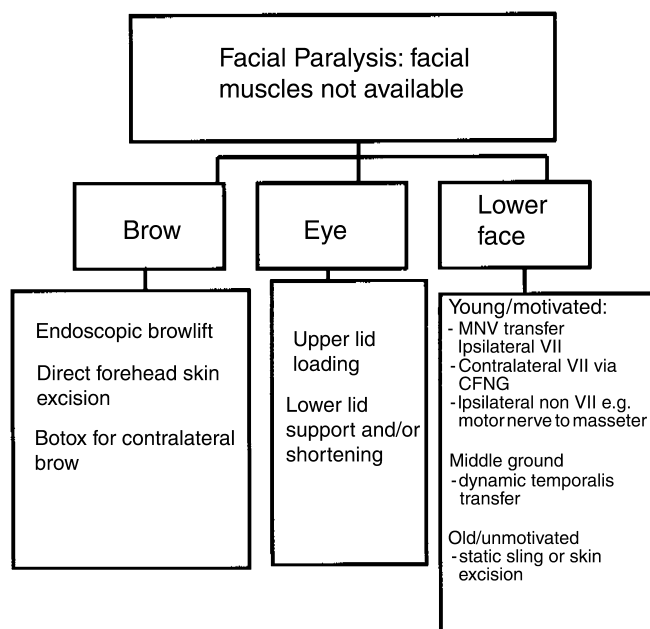


FIGURE 2 Algorithm for evaluation and treatment of facial paralysis—part 2.

particular problems with each region. We present those techniques which, in our experience, work best in each situation.

Upper Face and Brow Region

Brow ptosis can result in very obvious asymmetry at rest. It may also result in obstruction of the visual axis on upward gaze. We feel that static techniques work best for correcting brow ptosis (23–25); dynamic muscle transfer techniques such as frontalis transfer do not work as well because when they do provide dynamic function, the direction of pull is unnatural.

Endoscopic brow lifting is quite valuable for the majority of patients with unilateral brow paralysis. Standard cosmetic endoscopic browlift techniques are readily adaptable. The results appear to be durable for at least one year with an acceptable aesthetic outcome. Recently, we have been using the Endotine absorbable anchor (Coapt Systems, Palo Alto, CA) for both pediatric and adult patients, with acceptable initial results. It is important to consider the contralateral (nonparalyzed) side also. If the contralateral side is ptotic, then a bilateral browlift should be considered. If it is not ptotic, and its activity results in obvious asymmetry, then a frontal branch neurectomy, either surgically or with botulinum toxin, should be considered.

If there is marked bilateral brow ptosis superimposed upon a unilateral facial paralysis (as can occur in elderly patients), then a direct brow lift can be quite useful. One must examine the patient while upright to determine to what extent lid closure may be compromised by such an excision, however. In this procedure, the skin and muscle superior to the brow are resected in a modified ellipse to elevate the brow (26).

Eyelids

In general, we prefer using gold weights for the upper lid and lid shortening procedures for the lower lid. The use of gold weights results in the ability to completely close the eye in 82% (27). Dynamic pedicled or free muscle transfers (28) are generally not necessary for eyelid rehabilitation. Sadiq and Downes advocated preventive eyelid surgery for all patients diagnosed with permanent facial palsy or for those in which corneal exposure has occurred. In this study, patients with transient facial nerve palsies would only receive eyelid procedures if they had evidence of corneal exposure (4). In addition, they proposed treatment of corneal exposure where the status of the facial nerve was unclear with botulinum toxin injection into the levator palpebrae superioris muscle.

Although gold weight implantation alone usually provides adequate corneal protection (29), equal attention should be given to the lower eyelids. Lower lid ectropion can result in corneal exposure. The timing of lower lid tightening procedures is different from upper lid loading procedures. Gold weights can be implanted at the time of an ablative surgery such as a parotidectomy or a temporal bone tumor resection in which the facial nerve is intentionally sacrificed and was preoperatively affected. Lower lid procedures should be delayed, however, until the degree of lower lid laxity is known. Gold weight implantation and lower lid shortening can, however, be performed under the same anesthetic. If this is chosen, the gold weight should be implanted before the lower lid shortening procedure is performed in order to judge the amount of lower lid tightening required. We prefer lateral wedge resections of the lower lid.

Lower Face

Management decisions regarding the lower face are based largely on the age of the patient and the need for a dynamic reconstruction. In general, the younger patients and more highly motivated patients are best managed with a dynamic microvascular reconstruction. This involves the transplantation of a segment of the gracilis muscle to the face. The innervation of the muscle is critical to the success of the procedure. This will be described in detail in the upcoming paragraphs. For older adults who are interested in an immediate repositioning of the distorted structures of the lower face, a static sling is most effective. The static sling not only supports the drooping oral commissure but also prevents its displacement when the normal side is activated. The results are seen almost immediately after surgery. The static sling can be carried out utilizing a woven back and forth tendon technique whereby the tendon graft is anchored to the zygomatic arch and woven into the oral commissure and upper lip. This can also be effectively carried out with a sheet of fascia lata, which is anchored to the temporalis fascia and again secured to the corner of the mouth and upper lip.

Dynamic reconstruction may be carried out with regional muscles although it is preferable to utilize the free microvascular tissue transfer technique. The nonmicrovascular dynamic transfer which we have found to be most effective is the McLaughlin procedure (30), in which the coronoid process of the mandible is removed and fascial strips are used to link the temporalis to the lips. It is important to insert the strips into the midline of the lips, otherwise progressive relaxation will result in distortion of the lips. The Rubin temporalis transfer (31), consists of a turndown of the temporalis muscle with fascial extensions into the lips. It can effectively restore some motion to the mouth but results in an unsightly bulge where the muscle is turned over the zygomatic arch. This leaves a significant temporal hollow. Usually this temporal hollow is filled with a custom polyethylene implant (*Medpor, Porex, Fairburn*).

The dynamic microvascular transfers referred to above are the most effective reconstructions available at the present time for a young or well-motivated patient with facial paralysis. In general, a segment of the gracilis muscle is harvested from the thigh and transplanted to the face. It is appropriately positioned to support the lower lip, provide elevation for the commissure and lower lip to facilitate speech, and with elevation of the commissure and upper lip create a smile.

The procedure is generally carried out in two teams. One team prepares the face. Through a preauricular incision with a submandibular extension, a pocket is created. Anchoring sutures are carefully placed into the oral commissure and upper lip. If elevation of the lower lip is important, such as in those patients with commissure droop, a suture is placed in the lower lip as well. With traction on the sutures a nasolabial crease is produced that should match as closely as possible the opposite or normal side (Fig. 3). The facial vessels are prepared as they will be utilized to revascularized the transplant. It is important to remove some bulk in the cheek to reduce the likelihood of asymmetry at rest with fullness. The subcutaneous fat that overlies the future muscle can be removed. Care should be taken to leave the fat beneath the dermis to avoid dimpling of the skin to the muscle. In addition to the subcutaneous fat, it is helpful to remove the buccal fat pad or part thereof.

Selection of the nerve which will innervate the transplant is crucial. If there is a branch of the ipsilateral facial nerve available for use then this is preferable. It should however be the specific branch that goes to the zygomaticus major and minor and the levators. This will make possible a symmetrical smile.



FIGURE 3 With appropriate suture placement, a well-defined nasolabial crease can be created.

If there is not an ipsilateral facial nerve branch available, the second choice is the contralateral seventh nerve. Again the specific branches to the zygomaticus major and minor should be identified and care should be taken to leave other branches available to innervate the normal side. This is done via an open technique with the aid of a nerve stimulator. The specific branches are selected and connected to a sural nerve graft. We prefer to use a short nerve graft which is banked in the upper buccal sulcus opposite the canine on the paralyzed side. The nerve graft thus courses from the mid cheek on the normal side where the contralateral seventh nerve branches have been identified, to the upper buccal sulcus on the paralyzed side. Under high power magnification, the nerve repair is carried out between the sural nerve graft and the selected branches of the normal facial nerve. An interval of nine months is allowed to pass for the nerve to regenerate and be available to innervate the muscle transplant. It is then used to power our segmental gracilis muscle.

If the facial nerve is not available on either the ipsilateral or the contralateral side, a microneurovascular transfer can be carried out with innervation via another regional motor. We have found the motor nerve to masseter to be most effective in this situation. It can be identified on the undersurface of the masseter coursing downward and anteriorly from the upper portion of the masseter just below the zygomatic arch and just anterior to the temporomandibular joint. Dissection is carried through the masseter to its undersurface where with the aid of the nerve stimulator the small motor nerve to masseter is identified. It is traced distally and then cut and then reflected upward to be in a more superficial position for nerve coaptation. In situations where there is no facial nerve on either side the procedure is done bilaterally but spaced three to six months apart. Even though precise symmetry cannot be obtained and full spontaneity is not possible because a nonfacial nerve motor is being utilized, we have been most pleased with the results.

The muscle is harvested through an upper inner thigh incision taking care not to bring the incision into the groin crease and not to carry it distally into the middle third of the thigh. Only the segment of muscle required is harvested. This generally is about 40% to 50% of the circumference of the muscle (Fig. 4). Reduction of the width of the muscle is crucial to avoid excess bulk in the reconstructed cheek. The length of the muscle required is the functional length from the oral commissure to the root of the helix. We add 1 cm on each end for suturing. The required length is harvested from the thigh and transplanted to the face. The remaining muscle is left in situ.

In order to reduce the likelihood of the transplanted muscle from slipping from its insertion in the oral commissure and upper lip, mattress sutures are placed at the end of the muscle. The anchoring sutures previously placed in the commissure and lips are then passed beyond the mattress sutures. An additional bite is taken in the commissure and upper lip and then the suture is placed back again through the adjacent mattress suture. In this way, the muscle is secured in the selected location and assurance is made that it will not slip from this location. The sutures are tied down and the insertion secured. Then the microvascular anastomoses are carried out. We prefer to use the facial vein which has been dissected vertically upward and facial artery, which have been dissected anteriorly. These are divided and transposed



FIGURE 4 The gracilis muscle is divided so that only 40–50% of its circumference is generally used, to limit bulk in the cheek.

posteriorly for ease visualizing the vascular repairs. The facial vein is anastomosed to the larger vena comitans of the gracilis pedicle. The facial artery is anastomosed to the artery of the gracilis. The motor nerve to gracilis is then repaired. This is done to the ipsilateral facial nerve when this is available. In this situation, it is preferable to put the nerve repair beneath the muscle. When the ipsilateral facial nerve is not available the second choice is the contralateral facial nerve with an extension via the short sural nerve graft. In this situation, the motor nerve to gracilis is tunneled anteriorly through the cheek and into the buccal sulcus. An enlarged buccal sulcus incision is made and the nerve coaptation is carried out here under high magnification. Care is taken to achieve a nerve repair that has no tension and is as accurate as possible. Where there is no facial nerve available either ipsilaterally or contralaterally then the motor nerve to masseter is used. In this situation, the nerve to gracilis can be shortened and a direct coaptation between this nerve and the motor nerve to masseter is carried out. Again this is done without tension and under high magnification.

After the nerve repair is completed the vascular anastomoses are reassessed and assurance is made of the complete vascularity of the muscle. The muscle is then placed under appropriate tension and its origin is secured to the temporalis fascia. The tension utilized is that which just barely places some tension at the oral commissure and upper lip. There is no definitive movement at this site, but the muscle is ready to produce movement upon contraction. The muscle is secured through mattress sutures to the temporalis fascia. Care is taken to place the vector of movement of the muscle as closely as possible to the opposite side. In general, this courses just below the malar prominence toward the anterior helical margin and the upper portion of the tragus (Fig. 5).



FIGURE 5 Segmental gracilis muscle in place.



FIGURE 6 Unilateral facial paralysis reconstruction with cross-facial nerve graft and segmental gracilis muscle transplant. (A) Preoperatively at rest. (B) Preoperatively with smile. (C) Postoperatively at rest. (D) Postoperatively with smile.

After thorough irrigation and careful inspection for hemostasis the wound is closed in layers over a Penrose drain which exits in the postauricular region.

The time for muscle reinnervation will vary with the length of the motor nerve to gracilis utilized. When the muscle is innervated by a cross-facial nerve graft, it may take four to six months to function (Fig. 6A–D). When the motor nerve to masseter is used, reinnervation will occur relatively rapidly over the course of about 8–10 weeks (Fig. 7A–D). By utilizing either the ipsilateral or contralateral facial nerve, movement should be quite spontaneous. Thus, no relearning for spontaneity is necessary. Some simple exercises to improve muscle excursion and symmetry are helpful. When a different motor is used, such as the motor nerve to masseter, simple exercises with biofeedback in front of a mirror are often helpful to improve the level of spontaneity. These are recommended after muscle function has been achieved on the second side.



FIGURE 7 Bilateral facial paralysis reconstruction with gracilis muscle transplant innervated by the motor nerve to masseter. (A) Preoperatively at rest. (B) Preoperatively with attempted smile. (C) Postoperatively at rest. (D) Postoperatively with smile.

RESULTS

The results of muscle transplantation for facial paralysis can be quite dramatic. Although we are not able to replicate completely normal appearance and function, considerable benefit to the patient can be provided. We have improved muscle excursion we feel with the use of a longer segment of muscle, a larger component of contralateral facial nerve and a short sural nerve graft which does not have any branches. We feel that these factors have provided increased neural input into the muscle in the reconstruction of unilateral facial paralysis (Fig. 6A–D). In bilateral cases, symmetry continues to be a problem as it is very difficult to provide muscle insertion and movement in the exact same location on both sides. However, excellent smile restoration can be accomplished in bilateral cases particularly in situations where no movement was present preoperatively (Fig. 7A–D).

PEDIATRIC FACIAL PARALYSIS: SPECIAL CONSIDERATIONS

Children can present with either acquired or congenital facial paralysis. Acquired facial paralysis in children is usually the result of trauma. This may be a direct injury to the extracranial component of the facial nerve or a closed head injury with damage to the intracranial component. Unfortunately, it may also be iatrogenic from surgical excision of vascular and lymphatic lesions extracranially or in the process of excision of intracranial neoplasms. Less commonly, in contrast to adults it may be the results of infection. Congenital conditions that may present with congenital facial paralysis include Mobius syndrome, asymmetric crying facies, congenital upper lip paralysis, Poland syndrome, and Goldenhar syndrome. Issues related to syndromic conditions, such as genetics, involvement of other cranial nerves, neuropsychologic concerns, growth, and timing of treatment must all be considered. In the case of Mobius syndrome in particular, multiple cranial nerves may be involved. For example, the hypoglossal nerve may be impaired, precluding its use in facial reanimation. Genetic counseling can be helpful in elucidating other associated anomalies as well as providing guidance to the family regarding subsequent offspring.

The reconstruction of the ability to smile is a high priority in the management of these patients. The facial muscles are generally not available in most cases of pediatric facial paralysis, and so for these cases we usually advocate microneurovascular muscle transfer. Additionally, facial paralysis in young children can result in undergrowth of the affected side, especially of the malar eminence. Free muscle transfers usually address this problem as well. The gracilis muscle works well for recreating the smile (32,33). It can be innervated by the ipsilateral facial nerve when available, the contralateral facial nerve as a second choice and in cases where the facial nerve is not available on either side, by another regional motor—most often the motor nerve to masseter (34). On occasion branches of the spinal accessory nerve (XI) may be used if the trigeminal is not available. We discourage use of the hypoglossal because of the potential negative effects of tongue atrophy and speech problems. We also do not recommend the use of the phrenic nerve since young children are obligate diaphragmatic breathers. The masseteric branch of the V nerve can supply adequate numbers of axons to provide innervation of the gracilis. In a short period of time the children adapt well and can “smile” even without clenching the teeth. Although the nerve can be challenging to locate intraoperatively, it does provide excellent muscle excursion.

ADJUNCTIVE PROCEDURES

Botulinum Toxin

Botulinum toxin can be used to augment neuromuscular retraining by reducing synkinesis and hypertonicity (4). Hyperactive muscles can be injected to reduce hypertonicity. In order to improve symmetry, the normal muscle on the contralateral side can be injected if the affected muscle remains hypotonic (35–37).

Lower Lip Procedures

Lower lip paralysis can lead to oral incompetence, manifested by lip droop, drooling, and difficulty with chewing. The inactivity of the lower lip depressors also results in an asymmetric smile, even if a muscle is transferred to produce this motion. This may even be the most noticeable feature following reconstruction. The flaccid lower lip can be addressed by wedge resection in concert with autologous fascial grafting (38). While some have investigated the use of local muscle flaps or free tissue transfers to restore lower lip depressor function (39,40), or advocated surgical resection of the contralateral depressor (41), our preference is to use botulinum toxin to paralyze the contralateral side.

Procedures to Manage Facial Aging in Facial Paralysis

Longstanding facial paralysis produces two major effects with age, both of which detract from symmetry. First, typical rhytids produced by muscle activity with aging do not develop. Second, the paralyzed side is more susceptible to the effects of gravity, and thus facial ptosis occurs



FIGURE 8 Successful outcome of unilateral facial paralysis reconstruction using a short sural nerve graft and segmental gracilis muscle transplant.

earlier. The mainstay of treatment of accelerated asymmetric aging consists of excisional or static procedures. Excisional browlifting is most effective in correcting significant brow ptosis in older individuals. Asymmetric facelifting is useful in correcting the facial ptosis of the paralyzed side (42). In younger individuals who desire a relatively simple procedure, midface suspension procedures have been advocated (43). Suborbicularis oculi fat pad (SOOF) suspension has also been proposed as a method to improve periorbital contour (44).

SUMMARY

In summary facial paralysis is a multifaceted problem. It is imperative to ensure corneal protection either conservatively or surgically. A detailed clinical assessment can lead the surgeon to a sound diagnosis. Then a treatment plan can be formulated. This will vary with the patient's age, needs, and wishes. Both static and dynamic reconstructions have a role in facial paralysis surgery. Microvascular transplantation of the gracilis muscle has proven to be most effective. This can be successfully innervated by the ipsilateral facial nerve or by the contralateral facial nerve via a cross-facial nerve graft. (Fig. 8). Especially effective for bilateral facial paralysis is the segmental gracilis muscle transplant innervated by the motor nerve to masseter—a branch of the trigeminal.

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Index

- Abbe flap, 49
- Abscess
 - lacrimal sac, 130
- ACC. *See* Aplasia cutis congenita
- Acquired facial paralysis, 369
- Actinic keratoses
 - premalignant
 - ablating, 316
- Actinomyces*, 135
- Acute dacryocystitis, 136
- Acute debridement
 - traumatic tattoo, 196
- Acute spastic entropion, 34
- Aesthetic craniofacial surgery
 - techniques, 321
- Aesthetic nasal dorsum, 267
- After plug grafts
 - hair transplantation, 83
- AHA. *See* Alpha-hydroxy acids
- Airway evaluation
 - VPD, 116
- Alar cheek junction, 267
- Alar rim modification, 265–266
- Alar-cartilage lift, 302
- Alar-columellar relationship, 269
- Alloderm, 348
 - synthetic dermal elements, 175
- Allogenic collagen
 - scars, 60
- Alloplastic materials
 - chin, 353–354
- Alopecia
 - androgenic, 78
 - androgynic, 80
 - open subperiosteal approach, 334
 - scalp, 166
- Alpha-hydroxy acids (AHA), 316, 318
- Amino-propionitrile, 58
- Androgenic alopecia, 78
- Androgenic hair loss, 76
- Androgynic alopecia, 80
- Anesthesia
 - blepharoplasty, 215
 - eyelid surgery, 24
 - rhinoplasty, 272
- Anesthetic units
 - facial burns, 173
- Anterior hair
 - hair transplantation, 86
 - preoperative oblique view, 76
- Anterior hair loss, 77, 79
- Anterior lacrimal crest suture, 149
- Anterior lamellar reconstruction, 37–38
- Anterolateral thigh flap
 - cheek reconstruction, 205–206
- Antibiotic ointment-coated intranasal Silastic splints, 287
- Aplasia cutis congenita (ACC), 345–348
 - clinical findings, 346
 - complications, 346–347
 - diagnosis, 346
 - differential diagnosis, 346
 - epidemiology, 345–346
 - etiology, 345
 - lesions, 346qqrc
 - operative therapy, 347
 - pathophysiology, 346
 - treatment, 347
- Aponeurotic blepharoptosis, 28
- Argon laser, 5
- Argon-pumped tunable dye laser, 4
- Artecoll, 61
- Autologous collagen
 - scars, 60
- Autologous fat injection, 60–61
- Axioms, 125
- Baby-sitter technique, 363
- Bacitracin, 144
- Baldness
 - hair transplantation, 81
- BAPN. *See* Beta-amino-propionitrile
- Bardach two-flap palatoplasty, 340
- Basal cell atypia, 318
- Basal cell carcinoma
 - cheek reconstruction, 208
- Bell's palsy, 361
- Berkley, William, 302
- Beta-amino-propionitrile (BAPN), 58
- Biçhat's fat pad
 - excision, 333
 - exposure, 328
- Bilateral cleft nasal deformity, 305
 - bilateral rim incisions, 305
 - illustration, 307, 308
- repair
 - outcomes, 307–311
 - secondary, 307–311
- Bilateral facial paralysis
 - gracilis muscle transplant, 370
- Bilateral incomplete cleft, 310
- Bilateral lower blepharoplasty, 220
- Bilateral rim incisions
 - bilateral cleft nasal deformity, 305
- Bilobed flap design
 - lateral nasal deflect, 66
- Biopsychosocial being
 - preoperative patient, 314

- Blepharoplasty, 24–27, 211–221
 - anesthesia, 215
 - author's surgical technique, 215
 - complications, 31, 218–219
 - etiology, 211
 - general, 215
 - infection, 220
 - lower, 25, 26–27
 - bilateral, 220
 - lower blepharoplasty technique, 26–27
 - lower lid, 216
 - markings, 215
 - patient anatomy, 211–213
 - postoperative care, 218
 - secondary, 220–221
 - surgical considerations, 213–215
 - upper blepharoplasty technique, 25–26
 - upper eyelids, 216
- Blepharoplasty technique
 - upper, 25–26
- Blepharoptosis, 27–31
 - aponeurotic, 28
 - facial nerve synkinesis, 30
 - management, 29–30
 - MRD, 28
 - myogenic, 29
 - neurogenic, 28–29
 - neuromuscular, 28
 - overcorrected, 23
- Block techniques
 - lip anesthesia, 46
- Bony dorsum
 - reduction, 275
- Bony skull defect
 - plain film, 348
- Botulinum toxin, 366, 371
- Botulinum toxin A
 - injection, 101
 - temporalis muscle injection, 102
- Bovine collagen
 - scars, 60
- Broken-line closure
 - scars, 63
- Brow ptosis, 364
- Burned cheek
 - bilateral reconstruction, 187
- Burns. *See also* Facial burns
 - oral injuries, 46
- Burrow's triangle excisions, 64
- Cadaver dissection
 - ITF, 324
- Calcium channel blockers
 - injections, 164
- Canalicular laceration, 131
- Canalicular obstruction, 132
 - treatment, 132–133
- Canaliculitis, 133–136
 - clinical findings, 133–134
 - epidemiology, 134
 - microbiology, 135–136
 - pathophysiology, 134–135
 - photograph, 134
 - treatment, 136
- Candida krusei*, 143
- Candida parakusei*, 143
- Candida parapsilosis*, 143
- Cantholysis, 39
- CAPS. *See* Computer-aided plastic surgery
- Carbon dioxide lasers, 5
- Carotid arteries, 118
- Cartilage
 - grafts for facial burns, 170
 - physical models, 295
- Caudal margin
 - LLC, 273
- Caudal septum, 269
- CDCR. *See* Conjunctivodacryocystorhinostomy
- Cephalexin, 288
- Cephalic trim
 - LLC, 283
 - rhinoplasty, 278
 - ULL, 283
- Cerebral herniation, 348
- Cervical contracture
 - anterior view, 176
 - lateral view, 176
- Cervicofacial flap, 185
 - cheek reconstruction, 184–188, 226–228
 - medially based, 186–187
- Cheek
 - aesthetic subunit, 224
 - burn, bilateral reconstruction, 187
 - gracilis muscle, 367
 - soft-tissue sarcoma, 204
 - vascular anatomy, 224
 - volume restoration, 331
 - lateral views, 333
- Cheek reconstruction, 183–191, 201–209, 223–238
 - ablative surgeries, 231
 - anatomy, 223
 - anterolateral thigh flap, 205–206
 - basal cell carcinoma, 208
 - cervicofacial flap, 226–228, 227, 228
 - cheek aesthetic subunit, 224
 - complications, 233–238
 - contour defects, 184–189
 - disruption of hairline, 238
 - donor vessels, 207
 - ectropion, 203, 233–238
 - evaluation, 223–224
 - facial esthetic principles, 209
 - facial nerves, 207–208
 - flap necrosis, 233–238
 - flap prefabrication, 233, 234
 - flap prelamination, 233, 235
 - free tissue transfer, 203–209, 231
 - full-thickness hair bearing scalp, 237
 - functional submental flap, 229
 - general principles, 201–202
 - laterally based cervicofacial flap, 186
 - local flaps, 202–203
 - parascapular flaps, 205
 - pectoralis flap, 228–230
 - perforator artery, 208
 - principles, 183
 - reconstructive methods, 236
 - rectus abdominis, 232
 - rhomboid flaps, 225
 - round block “purse-string”
 - suture method, 189
 - technique, 190
 - scapular flaps, 205
 - insertion, 206
 - SCC, 188

- [Cheek reconstruction]
 - skin grafts, 225–226
 - soft-tissue sarcoma, 207
 - submental artery flap, 203
 - submental flap, 228
 - supraclavicular flap, 230–231
 - technique, 187–188
 - tissue expansion, 226
 - trapezius flap, 230
 - treatment, 224–232
 - upper lip, 188
 - vascular anatomy of the cheek, 224
 - V-Y flap, 225
- Cheek rotation advancement flap, 202
- Cheek rotation flap, 202
- Chemical peeling agents, 315
- Children
 - congenital facial paralysis, 369
 - facial burns, 159
 - facial paralysis
 - adjunctive procedures, 371–372
 - considerations, 369–371
 - lower lip procedures, 371
 - palatal surgery, 338
 - Romberg's disease, 72
- Chin
 - aesthetic concepts, 353
 - aesthetic manipulation, 358
 - alloplastic materials, 353–354
 - clinical landmarks of region, 352
 - facial aesthetics, 351
 - implants
 - designs, 354
 - varieties, 354
 - manipulation, 358
 - pad ptosis, 357
 - reduction
 - surgical technique, 356
- Chronic dacryocystitis, 136
- Chronic inflammation
 - lacrimal sac obstruction, 138
- Cicatricial entropion, 32, 34
- Cleft deformity
 - unilateral, 301
- Cleft lip
 - unilateral, 306
- Cleft nasal deformity
 - bilateral, 305
 - management, 301–311
 - secondary repair, 311
 - unilateral
 - illustration, 302, 304
 - photograph, 306
 - secondary repair, 304
- Cleft palate, 337–343
 - anatomy, 337–338
 - complications, 342–343
 - deformities, 337
 - lifelong impact, 343
 - embryology, 338
 - epidemiology, 337
 - postoperative care, 342
 - speech characteristics, 116
 - surgical methods, 339–342
 - timing of surgery, 338
- Cleft rhinoplasty
 - ideal time, 311
 - secondary, surgical technique, 304
- Clindamycin, 339
- Cloth folding techniques
 - forehead flap reconstruction, 293
- Code of Hammurabi
 - lacrimal outflow system, 130
- Cognitive domain
 - soft-tissue defects, 292
- Collagen
 - scars, 60
- Columellar defects
 - facial burns, 170
- Columellar-lobular junction, 273
- Columellar strut, 281
- Columellar-tip graft, 282
- Commisuroplasty results, 175
- Computer-aided plastic surgery (CAPS), 297
 - pre-op planning, 297–298
- Condylar head fractures, 246
- Congenital dacryocystitis
 - treatment, 150
- Congenital facial paralysis
 - children, 369
- Congenital lacrimal sac obstruction, 138
- Congenital microtia
 - three-dimensional model
 - of cartilage, 295
 - of skin, 295
- Congenital nerve palsy, 364
- Conjunctivodacryocystorhinostomy, 36
- Conjunctivorhinostomy (Jones) tube, 133, 134
- Continuous wave (CW) lasers, 2
- Contour defects
 - cheek reconstruction, 184–189
- Copper vapor laser, 4
- Corneal irregularities, 23
- Corneal protection
 - facial paralysis, 360–361
- Corrugator muscle, 327
- Cortical spreading depression (CSD), 98
- Corticosteroids, 57
- Cosmetic endoscopic brow lift techniques, 364
- Cottle elevator, 277
- Craniofacial defects
 - microsurgical reconstruction, 69–75
 - severity, 67
- Craniofacial surgery
 - aesthetic techniques, 321
- Cross-facial nerve grafting, 364
- CSD. *See* Cortical spreading depression
- Cutaneous allodynia
 - MH, 98
- Cutaneous submental incision, 353
- CW. *See* Continuous wave (CW) lasers
- Dacryocystectomy
 - primary indication, 148
- Dacryocystitis, 136
 - acute, 136
 - chronic, 136
 - complications, 144
 - congenital treatment, 150
 - drainage, 144
 - epidemiology, 137
 - incision, 144
 - microbiology, 143–144
 - neonatal, 149
 - epidemiology, 149–150
 - microbiology, 150

- [Dacryocystitis]
 - predisposing factors, 137
 - radiological evaluation, 137–138
 - treatment, 144, 150
- Dacryocystorhinostomy, 145
- Dacryoliths
 - nasolacrimal duct obstruction, 142
- Data fusion
 - perioperative applications, 298
- Debridement
 - traumatic tattoo, 196
- Deep rhytids
 - softening, 333
- Deep soft-tissue suspension
 - methods, 322
- Deltpectoral flap, 187
- Depressor supercillii muscles, 97
- Dermabrasion, 55–63
 - disadvantages, 62
- Dermal orbicular pennant, 8–9
 - inferior border, 8
- Dihydrotestosterone (DHT), 81
- Dingman mouth gag, 339
- Diplopia, 27
- Distant flaps
 - lip reconstruction, 52–53
- Donor site
 - hair transplantation, 87
- Donor vessels
 - cheek reconstruction, 207
- Donor's hair
 - hair transplantation, 86
- Dorsum
 - aesthetic nasal dorsum, 267
- Double opposing Z-plasty palatoplasty, 341–342
- Dry eye disease, 21, 23
- Ear
 - facial burns, 176–177
 - facial fractures, 243
- Ectropion, 31–32
 - cheek reconstruction, 203, 233–238
 - facial burns, 173
 - lower lid, 366
 - mechanical, 32
 - orbital septum, 218
 - paralytic, 32
 - tarsal strip technique, 31–32
 - upper lip, 173
- Electrical burn
 - oral commissure, 174
- Electrodiagnostic studies
 - facial paralysis, 362
- Elliptical strip
 - hair transplantation, 87
- Emergency tracheotomy, 241
- Endoforehead procedure, 325–327
- Endomidface procedure, 328–333
- Endonasal approach
 - advantages, 271
- Endophthalmitis
 - suture removal, 144
- Endoscopic facelift, 332
- Endoscopic forehead rejuvenation, 329
- Endoscopic midface procedure
 - suspension suture placement, 329
- Endoscopic midface rejuvenation, 329
- Endoscopic rhytidectomy technique, 331
- Endoscopic subperiosteal facelift, 325–334
 - complications, 334
 - full-face views, 330
 - postoperative care, 334
 - surgical technique, 325–334
- Entropion, 33–34
- Epiphora, 133
- Erbium:Yttrium-aluminum-garnet laser, 5
- Erythema, 316
- Estlander flap, 49
- Excision
 - lower lip lesion, 48
 - scars, 62
- External levator aponeurosis advancement
 - technique, 30–31
- Extraocular muscle injury, 27
- Extrinsic neoplasia
 - lacrimal sac obstruction, 139
- Eye(s)
 - facial burns, 168–169
 - facial fractures, 242–243
- Eyebrow reconstruction
 - facial burns, 167–168
- Eyelids
 - closure, 361
 - facial burns, 168–169
 - facial paralysis, 365
 - flaps, 38
 - full-thickness reconstruction, 38–40
 - healing, 40
 - lower
 - anatomy, 213
 - ectropion, 366
 - retraction, 35
 - plastic surgery, 21
 - reconstruction, 21–40
 - patient evaluation, 21–24
 - retraction, 34–35
 - surgery, 22
 - anesthesia, 24
 - upper
 - blepharoplasty, 216
 - retraction, 34–35
- Face muscles, lower
 - facial paralysis, 362
- Facelift
 - endoscopic, 332
 - hair loss, 80
 - tertiary procedures, 322
- Facial aging
 - characteristic features, 321
 - facial paralysis, 371
 - patient signs, 332
- Facial burns
 - adjunctive nonoperative techniques, 162–164
 - aesthetic subunits, 162
 - anesthetic units, 173
 - cartilage grafts, 170
 - cheek, 170–172
 - children, 159
 - columellar defects, 170
 - ear, 176–177
 - ectropion of the upper lip, 173
 - electrical burn of oral commissure, 174
 - extensive burn defects, 161

- [Facial burns]
 - eye, 168–169
 - eyebrow reconstruction, 167–168
 - eyelids, 168–169
 - facial deformities, 177
 - healing secondarily, 160
 - initial management, 157–178
 - lasers, 164
 - management, 157–178, 178
 - nasal deformity, 171
 - neck, 174–175
 - nose, 169–170
 - perioral area, 173
 - Phoenix Society, 178
 - psychologic issues, 177–178
 - reconstruction, 157–178, 165–177
 - reconstruction of forehead deformities, 167
 - scar contracture, 163, 175
 - silicone gel sheets, 164
 - skin grafts, 166
 - thermoplastic material, 163
 - topical burns, 158
 - wound contracture, 165
 - wound management, 159–161
 - Z-plasty, 166
- Facial cosmetic procedures
 - healing process, 314
- Facial esthetic principles
 - cheek reconstruction, 209
- Facial fractures, 241–252
 - ear, 243
 - eye, 242–243
 - mandible fractures, 243–244
 - neck, 242
 - nose, 243
 - physical examination, 241–243
 - scalp, 242
 - skin, 242
 - throat, 243
- Facial hemiatrophy, 70–73
 - neurologic symptoms, 70
- Facial lipodystrophy, 184
- Facial muscles
 - type of functions, 360
- Facial nerves, 359–360
 - cheek reconstruction, 207–208
 - divisions of, 359
 - synkinesis
 - blepharoptosis, 30
- Facial paralysis, 359–372
 - acquired, 369
 - aesthetic problems, 360–362
 - anatomy, 359–360
 - bilateral
 - gracilis muscle transplant, 370
 - children
 - adjunctive procedures, 371–372
 - complete, 362
 - congenital
 - children, 369
 - corneal protection, 360–361
 - electrodiagnostic studies, 362
 - evaluation, 362, 365
 - eyelids, 361, 365
 - facial aging, 371
 - functional problems, 360–362
 - incomplete, 362
- [Facial paralysis]
 - lower face muscles, 362
 - treatment, 362–367, 372
- Facial paralysis reconstruction
 - unilateral, 369
- Facial rejuvenation, 332
- Facial volume
 - restoration, 334
- Fat grafting, 333–334
- Fat injection
 - autologous, 60–61
- Fat pad
 - retro-orbicularis oculi, 323
- FEM. *See* Finite element mesh
- Fibrous attachments
 - medial crura, 284
- Fibrous ligaments
 - ULC, 259
- Finite element mesh (FEM), 296
- Fitzpatrick skin classes
 - traumatic tattoo, 197
- Flap. *See also* specific area: e.g., Forehead flaps; specific type: e.g., Gillies fan flap
 - cheek reconstruction
 - necrosis, 233–238
 - prefabrication, 233, 234
 - prelamination, 233, 235
- Flashlamp-pumped pulsed dye laser, 4
- Fluor-hydroxy pulse peel, 316
- Forehead deformities
 - reconstruction, 167
- Forehead flaps
 - cloth folding techniques, 293
 - nasal reconstruction, 292
- Forehead rejuvenation
 - endoscopic, 329
- Free tissue transfers, 52
 - cheek reconstruction, 203–209, 231
- Freer periosteal elevator, 49
- French catheter
 - chromic mattress, 148
- Frey's Syndrome, 74
- Front-temporal recession
 - hair transplantation, 89
- Frontal periosteum
 - internal brow proxy, 216
- Frontal sinus fractures, 251–252
- Frontalis muscle, 360
- Full-thickness eyelid reconstruction, 38–40
- Full-thickness hair bearing scalp
 - cheek reconstruction, 237
- Full-thickness skin grafts, 14–15
 - strengths, 14
 - weaknesses, 14–15
- Functional submental flap
 - cheek reconstruction, 229
- Gillies fan flap, 50
- Glabellar flap, 15
- Glycerin monostearate, 316
- Golden Peel, 316
- Gracilis muscle
 - bilateral facial paralysis, 370
 - cheek, 367
 - transplant, 370
- Growth factors
 - topical, 318

- Hair
 - anterior
 - preoperative oblique view, 76
 - transplantation, 86
 - growth after transplantation, 82
- Hair loss
 - after a facelift, 80
 - androgenic, 76
 - anterior, 77, 79
 - hair transplantation, 83, 84
 - women, 78
- Hair transplantation, 77–90
 - after plug grafts, 83
 - anterior hair, 86
 - associated patterns and types of
 - baldness, 81
 - donor site, 87
 - donor's hair, 86
 - elliptical strip, 87
 - extensive hair loss, 84
 - facial vascular malformation, 90
 - front-temporal recession, 89
 - graft insertion, 89
 - hair growth after, 82
 - hair loss, 83
 - hairline construction, 85
 - micrografts, 88
 - occipital area, 85
 - parietotemporal flap, 76
 - patient evaluation, 81–85
 - plug grafts, 83
 - surgical technique, 86–89
 - Uebel technique, 88
- Hairline
 - construction, 85, 238
- Healing
 - facial cosmetic procedures, 314
 - normal wound, 56–57
 - by secondary intention
 - facial burns, 160
 - medial canthus, 13–14
- Hemostasis, 56, 286
- Herpes, 134
- Herpetic keratitis, 23
- Hertel exophthalmometer, 249
- Hydrocodone, 288
- Hyperpigmentation disorder, 319
 - formulation therapy, 319
- Hypertrophic scars, 67, 160
 - radiotherapy, 58
- Iatrogenic injury
 - lacrimal sac, 140
- Idiopathic (Bell's) palsy, 361
- Incision-open approach
 - rhinoplasty, 273
- Incomplete cleft
 - bilateral, 310
- Infection
 - blepharoplasty, 220
 - nasolacrimal duct obstruction, 142
- Inferior retinacular lateral canthoplasty, 9–10
 - strengths, 9
 - technique, 9
 - weaknesses, 9–10
- Inferior turbinate hypertrophy
 - causes, 270
- Inferior turbinoplasty, 277–278
- Inferiorly based cervicofacial flaps, 185
- Inflammation, chronic
 - lacrimal sac obstruction, 138
- Infraorbital nerve
 - intraoral approach, 46
- Infratip lobular graft, 282
- Integra
 - synthetic dermal element, 175
- Intercanthal distance
 - rhinoplasty, 264
- Interdomal sutures, 280
- Intermediate temporal fascia (ITF)
 - cadaver dissection, 324
 - division, 325
- Internal brow proxy
 - frontal periosteum, 216
- International Headache Society, 96
- Intralesional injections
 - triamcinolone, 164
- Intraoral approach
 - infraorbital nerve, 46
- Intraoral incision
 - osteotomies, 355
- Invasive cosmetic dermatologic treatments, 313
- Involutional entropion, 31, 33
- Ipsilateral facial nerve
 - facial paralysis, 363–364
- Ipsilateral proximal stump
 - facial paralysis treatment, 363
- Ischemia, 70
- ITF. *See* Intermediate temporal fascia (ITF)
- Jessner's solution, 316
- Jones conjunctivorhinostomy, 133
- Jones tube, 133
 - placement, 134
- Karapandzic flap, 49–50
- Keloids, 67
 - radiotherapy, 58
- Keratopathy
 - exposure, 214
- Krypton laser, 5
- KTP laser, 4–5
- Labiomental fold (LF), 351
- Lacrimal canalicular system, 130–132
 - clinical findings, 131
 - treatment, 131–132
- Lacrimal crest suture
 - anterior, 149
- Lacrimal drainage system, 35–36
- Lacrimal mucocele, 137
- Lacrimal outflow
 - iatrogenic causes, 129
- Lacrimal outflow system, 129–150, 130
 - anatomy, 130
 - Code of Hammurabi, 130
- Lacrimal sac, 136–128
 - abscess, 130
 - failures in management, 141–142
 - history, 130
 - iatrogenic injury, 140
 - mid face trauma, 140
 - obstruction
 - associated nasal disease, 138–139
 - causes of obstruction, 138–139
 - chronic inflammation, 138

- [Lacrimal sac
 - obstruction]
 - congenital variations, 138
 - extrinsic neoplasia, 139
 - periosteum, 141
 - trauma, 139–141
 - tumors, 139
 - types of injuries, 139
- Lactobionic acid, 318
- Lagophthalmos, 9
- Lamellar reconstruction
 - anterior, 37–38
- Lasers, 1–5
 - basic principles, 1–2
 - facial burns, 164
 - penetration, 2
 - physical properties, 1
 - side effects, 1–2
 - traumatic tattoo, 197
- LASIK, 24
 - refractive surgery, 22
- Lateral canthal angle reformation, 12
- Lateral canthal tendon (LCT), 7
 - anatomy, 7
- Lateral canthopexy, 12–13, 219
 - strengths, 13
 - technique, 12–13
 - weaknesses, 13
- Lateral canthus
 - reconstruction, 7–19
- Lateral crura
 - resuturing, 283
- Lateral nasal deflect
 - bilobed flap design, 66
- Lateral nasal osteotomies
 - complications, 287
- Lateral rectus muscle
 - direct injury, 9
- Lateral tarsal strip, 10–12
 - strengths, 12
 - technique, 11
 - weaknesses, 12
- Laterally based cervicofacial flap, 184, 185
 - cheek reconstruction, 186
- LCT. *See* Lateral canthal tendon
- Le Fort fractures, 251
- LF. *See* Labiomentalar fold
- Lip(s). *See also* Lower lips
 - anesthesia block techniques, 46
 - augmentation, 53
 - conditions requiring reconstruction, 33
 - innervation, 43
 - mucosal flap advancement, 47
 - post-traumatic reconstruction, 45–46
 - reconstruction, 43–53
 - distant flaps, 52–53
 - visor flap, 52
 - upper
 - cheek reconstruction, 188
 - ectropion, 173
 - reconstruction, 45
 - vascular supply, 44
 - vermillion, 46–47
 - Lip-chin relationship
 - rhinoplasty, 262
 - Lip-collumelar junction
 - NAM, 303
 - LLC. *See* Lower lateral cartilage
 - Local flaps, 15–16
 - cheek reconstruction, 202–203
 - Lower blepharoplasty, 25, 26–27
 - bilateral, 220
 - primary goal, 26
 - Lower eyelids
 - anatomy, 213
 - blepharoplasty, 216
 - ectropion, 366
 - retraction, 35
 - Lower face muscles
 - facial paralysis, 362
 - Lower lateral cartilage (LLC), 258, 261, 273
 - Lower lips, 47
 - lesion excision techniques, 48
 - nasolabial flap technique, 49
 - pediatric facial paralysis, 371
 - Webster modified Bernard-Burow cheiloplasty, 51
 - Malar area
 - enhanced definition, 331
 - Mandible
 - defects, 74
 - fixation
 - principles, 245–247
 - types, 246
 - fractures
 - computed tomography, 244
 - occlusal view, 244
 - panoramic radiography, 244
 - periapical view, 243–244
 - plain films, 244
 - treatment, 245–247
 - Margin-reflex distance (MRD)
 - blepharoptosis, 28
 - Mastoidectomies, 74–75
 - Maxilla
 - maxillary defects, 73
 - Maxillectomy defect reconstruction, 203–204
 - McLaughlin procedure, 367
 - MCT. *See* Medial canthal tendon
 - Mechanical ectropion, 32
 - Medial canal ligaments, 263
 - Medial canthal tendon (MCT), 7
 - anatomy, 7
 - Medial canthopexy, 17–18
 - nontraumatic injuries, 17
 - strengths, 18
 - weaknesses, 18
 - Medial canthus
 - healing by secondary intention, 13–14
 - reconstruction, 7–19, 36–37
 - silicone, 148
 - suture, 143
 - Medial crura
 - fibrous attachments, 284
 - flaring, 281
 - resuturing, 283
 - sutures, 280, 281
 - Medial osteotomies, 285
 - rocker deformity, 285
 - Medial tarsal strip, 18–19
 - strengths, 18–19
 - Medial wall
 - radiofrequency dissection, 147
 - removal, 146
 - Medially based cervicofacial flap, 186–187
 - Medpor, 353

- Membranous septum
 - resection, 284
- Mental foramen, 351
- Mental nerve
 - anterior loop, 352
- Mentalis muscle, 351
- Mentalis reefing, 357
 - superior fixation, 357
- Mentoplasty, 351–358
 - bony procedures, 354
 - complications, 354, 355–356
 - patient assessment, 352–353
 - surgical technique, 354–355
- Methylprednisolone Dosepak, 288
- MH. *See* Migraine headache (MH)
- Micro neurovascular transfer, 367
- Microbiology
 - canaliculitis, 135–136
 - dacryocystitis, 143–144
 - neonatal dacryocystitis, 150
- Microdermabrasion, 316
- Micrografts
 - hair transplantation, 88
- Microsurgical reconstruction
 - craniofacial soft-tissue defects, 69–75
- Microsurgical transplant
 - recipient vessels, 75
- Microtia, congenital
 - three-dimensional model
 - of cartilage, 295
 - of skin, 295
- MIDAS. *See* Migraine disability assessment (MIDAS)
- Middle crura
 - tip graft, 281
- Midface
 - endoscopic rejuvenation, 329
 - endoscopic suspension suture placement, 329
 - fractures
 - radiologic workup, 245
 - lacrimal sac, 140
- Midline occipital region
 - MH, 104
- Migraine disability assessment (MIDAS), 96
- Migraine headache (MH), 93
 - clinical presentation, 93–94
 - cutaneous allodynia, 98
 - diagnostic criteria, 94
 - etiology, 98
 - identification, 100–102
 - improvement, 97
 - midline occipital region, 104
 - neurovascular bundle for control, 94
 - occipital trigger site, 103–108
 - patient selection, 99
 - semispinalis capitis muscle incision, 104
 - surgery, 93–108
 - surgical background, 94
 - surgical procedures, 102–108
 - temporal trigger site, 103
 - treatment, 99
 - trigger sites, 96, 99–100
- Mini-monoka canalicular stent, 132
- Mitomycin C (MMC), 148
- MRD. *See* Margin-reflex distance (MRD)
- Mucosal flap advancement
 - lip, 47
- Mucosal reconstruction, 47–48
- Mulliken's technique, 307
- Munion clamp
 - muscle fibers medial, 105
- Muscle fascia
 - orbital septum, 217
- Mustarde flap, 15
- Myocutaneous eyelid margin, 18
- Myocutaneous flaps, 16–17
 - strengths, 17
 - weaknesses, 17
- Myogenic blepharoptosis, 29
- NAM. *See* Nasoalveolar molding
- Nasal dorsum, 265
 - aesthetic, 267
 - rhinoplasty, 274–275
 - splints, 287
- Naso-orbital-ethmoidal fracture, 140
- Nasoalveolar molding (NAM), 301–302
 - lip-collumelar junction, 303
 - outcomes, 305
 - unilateral plate, 303
- Nasofacial analysis, 262
 - rhinoplasty patient, 262
- Nasofrontal analysis
 - rhinoplasty, 265
- Nasolabial flap technique, 48
 - lower lip technique, 49
 - suture placement, 367
- Nasolacrimal duct, 136
 - dilatation, 145
 - obstruction, 140
 - dacryoliths, 142
 - systemic disease, 142
 - systemic infections, 142
- Nasopharyngeal stenosis, 125
- Nd:YAG. *See* Neodymium yttrium-aluminum-garnet lasers
- Neck
 - facial burns, 174–175
 - facial fractures, 242
- Neodymium yttrium-aluminum-garnet (Nd:YAG) lasers, 3
- Neomycin, 144
- Neonatal dacryocystitis, 149
 - epidemiology, 149–150
 - microbiology, 150
- Nerve graft
 - facial paralysis treatment, 363
- Nerve palsy
 - congenital, 364
- Nerve repair
 - facial paralysis, 363
- Neurogenic blepharoptosis, 28–29
- Neuromuscular blepharoptosis, 28
- Neurovascular bundle for control
 - MH, 94
- Noninvasive measures
 - scars, 59–60
- Normal wound healing, 56–57
- Nose
 - burns, 171
 - deformity, 307
 - facial burns, 169–170
 - facial fractures, 243
 - fractured nasal bone, 286
 - lacrimal sac obstruction, 138–139
 - mucosa resection, 284
 - orbital ethmoid fractures, 250–251

- [Nose]
 - primary bilateral cleft repair, 305–307
 - primary unilateral cleft repair, 302–304
 - reconstruction
 - forehead flaps, 292
 - history, 299
 - saline, 288
 - septum ULC, 261
 - symptomatic airway obstruction, 277
 - turbinates, 260
 - vaults, rhinoplasty, 258–259
- Obstruction
 - lacrimal sac, 138–139
- Occipital area
 - hair transplantation, 85
- Occipital nerve
 - semispinalis muscle, 105
- Occipital trigger site
 - MH, 103–108
- On-site skin care clinic
 - benefits, 313–315
 - staffing, 313
- Open rhinoplasty
 - rationale for, 271
- Open subperiosteal approach
 - alopecia, 334
- Open subperiosteal facelift, 323–325
- Oral commissure
 - electrical burn, 174
- Oral injuries
 - burn injuries, 46
- Orbicularis oculi muscle, 360
 - paralysis, 361
- Orbital anatomy correction
 - orbital zygomatic fractures, 248–249
- Orbital septum
 - depiction, 217
 - ectropion, 218
 - leading edge of the muscle, 218
 - muscle fascia, 217
- Orbital volume
 - orbital zygomatic fractures, 248–249
- Orbital zygomatic fractures, 247–250
 - initial physical examination, 247
 - management, 247
 - orbital anatomy correction, 248–249
 - orbital volume, 248–249
 - radiographic assessment, 248
 - surgical approach to the orbit, 248
- Organs
 - generic models, 298
- Orthodontics, 263
- Osteotomy, 284–287
 - complications, 286
 - design of intraoral incision, 355
 - designs, 356
 - double-level, 286
 - fixation options, 356
 - low to high, 285
 - low to low, 285
 - medial, 285
 - reasons to perform, 284
 - titanium step-plate fixation, 355
 - versatility, 355
- Palatal fractures, 251
- Palatal lift, 118
- Palatal surgery
 - children, 338
- Panfacial fractures
 - staging, 252
- Paralysis reconstruction
 - unilateral segmental gracilis muscle transplant, 371
- Paralytic ectropion, 32
- Parascapular flaps
 - cheek reconstruction, 205
- Parasymphyseal fractures, 246
- Parietotemporal flap
 - hair transplantation, 76
- Parry-Romberg syndrome, 67
- Patient evaluation
 - eyelid reconstruction, 21–24
 - hair transplantation, 81–85
- Patient-specific three-dimensional models
 - soft-tissue defects, 294
- Pectoralis flap
 - cheek reconstruction, 228–230
- Perforator artery
 - cheek reconstruction, 208
 - vascular circumflex scapular artery, 208
- Perialar crescentic advancement flap, 52
- Periocular skin tumor
 - technique, 14
- Perioral area
 - anatomic landmarks, 45
 - facial burns, 173
- Periosteum
 - elevation
 - zygomatic arch, 324
 - lacrimal sac, 141
- Perlane, 61
- Permanent ocular misalignment, 27
- Pharyngeal flaps
 - appropriate level, 120
 - candidates, 119
 - inferiority, 122
 - lining, 120
 - outcomes, 120
 - patient specification, 121
 - superiority, 122
 - types, 120
- Phoenix Society
 - facial burns, 178
- Photothermic, 197–198
 - traumatic tattoo, 197
- Physical examination
 - facial fractures, 241–243
 - orbital zygomatic fractures, 247
 - VPD, 115–116
- Physical models
 - cartilage, 295
- Pierre Robin deformity, 338
- Pierre Robin sequence, 337
- Pityrosporum orbiculare*, 143
- Plastic surgery
 - eyelids, 21
 - goals, 291
 - three-dimensional imaging advances, 299
 - tissue simulation, 297
- Plug grafts
 - hair transplantation, 83
- PMMA. *See* Polymethylmethacrylate
- PMN. *See* Polymorphonuclear leukocytes
- Pogonion, 351

- Polymethylmethacrylate (PMMA), 60
- Polymorphonuclear leukocytes (PMN), 56
- Postoperative care
 - blepharoplasty, 218
 - cleft palate, 342
 - endoscopic subperiosteal facelift, 334
 - sphincter pharyngoplasty, 123
- Post-traumatic lip reconstruction, 45–46
- Premalignant actinic keratoses
 - ablating, 316
- Preoperative patient
 - biopsychosocial being, 314
- Preoperative planning
 - CAPS, 297–298
- Preoperative skin care program, 314
- Primary bilateral cleft nasal repair, 305–307
- Primary cleft nasal repair, 303
 - suture placement, 303
- Primary unilateral cleft nasal repair, 302–304
- Prosthesis
 - VPD, 117
- Provocative test
 - VPD, 116
- Psychologic issues
 - facial burns, 177–178
- Pulsed dye lasers, 3–4
- Purse-string
 - suture method
 - cheek reconstruction, 189
 - technique
 - complications, 190–191
 - schematic representation, 190
- Q-switched Alexandrite laser, 3
- Q-switched ruby laser, 2–3
- Q-switching technology, 197
- Radiance, 61
- Radiotherapy
 - hypertrophic scars, 58
 - keloids, 58
- Rectus abdominis
 - cheek reconstruction, 232
- Refractive surgery
 - LASIK, 22
- Remodeling
 - scar maturation, 56
- Resection
 - membranous septum, 284
 - nasal mucosa, 284
- Resorcin, 316
- Restylane, 61
- Result-oriented skin conditioning process, 313
- Resuturing
 - lateral crura, 283
 - medial crura, 283
- Retro-orbicularis oculi fat pad (ROOF), 323
- Rhinoplasty, 257–289
 - altering tip rotation, 283–284
 - anesthesia, 272
 - blood supply, 257–258
 - cephalic trim, 278
 - closed approach, 271
 - incision-open approach, 273
 - intercanthal distance, 264
 - lip-chin relationship, 262
 - nasal dorsum, 274–275
 - nasal function, 259–261
 - [Rhinoplasty]
 - nasal vaults, 258–259
 - nasofacial analysis, 262
 - nasofrontal analysis, 265
 - open approach, 270
 - operative technique, 270–289
 - postoperative management, 287–289
 - preoperative assessment, 261–272
 - secondary, 289
 - deformity, 289
 - skin envelope dissection, 274
 - spreader grafts, 278
 - tip modification, 278–283
- Rhomboid flaps
 - cheek reconstruction, 225
 - scars, 65
- Rhytidectomy
 - endoscopic, 331
- Rhytids
 - softening, 333
- Rim incisions
 - bilateral cleft nasal deformity, 305
- Rocker deformity
 - medial osteotomies, 285
- Romberg's disease, 71, 184
 - child, 72
 - scapular flap, 73
- ROOF. *See* Retro-orbicularis oculi fat pad
- Rotational flaps
 - scars, 65
- Round block "purse-string"
 - suture method
 - cheek reconstruction, 189
 - technique
 - complications, 190–191
 - schematic representation, 190
- Rubin temporalis transfer, 367
- Ruby laser complications, 3
- Sac lumen
 - catheter insertion, 149
- Sacral decubitus defect post excision, 65
- Salabrasion, 196
- Scalp
 - alopecia, 166
 - facial fractures, 242
 - full-thickness hair bearing
 - cheek reconstruction, 237
- Scanning electron microscopy
 - wound healing, 57
- Scapular flaps
 - cheek reconstruction, 205
 - insertion, 206
 - Romberg's disease, 73
- Scars, 55–56
 - allogenic collagen, 60
 - autologous collagen, 60
 - biochemical differences, 58
 - bovine collagen, 60
 - broken-line closure, 63
 - complications, 66–67
 - contracture
 - facial burns, 163
 - from second healing, 175
 - excision, 62
 - formation, 56–57
 - minimally invasive measures, 59–60

- [Scars]
 - noninvasive measures, 59–60
 - postoperative care, 66–67
 - remodeling, 56
 - revision, 55–67
 - rhomboid flaps, 65
 - rotational flaps, 65
 - surgical approach, 62
 - transition flaps, 65
 - W-plasty, 63
 - Z-plasty, 62
- Schirmer test, 361
- Scleroderma, 184
- Secondary bilateral cleft nasal repair, 307–311
 - outcomes, 307–311
- Secondary blepharoplasty, 220–221
- Secondary cleft rhinoplasty
 - surgical technique, 304
- Secondary rhinoplasty, 289
 - deformity, 289
- Segmental gracilis muscle, 368
- Semispinalis capitis muscle fibers munion
 - munion clamp, 106
- Semispinalis capitis muscle incision
 - MH, 104
- Semispinalis muscle
 - occipital nerve, 105
- Septal cartilage, 276
- Septal reconstruction, 275–277
- Septum, 260
 - abnormalities, 269
 - deformities, 269
 - separation, ULC, 275
- Silastic splints
 - antibiotic ointment-coated intranasal, 287
- Silicone
 - facial burns, 164
 - gel sheets, 164
 - intubation, 143
 - medial canthal suture, 143
 - medial canthus, 148
- Silvadene
 - facial burns, 158
- Silver sulfadiazine
 - facial burns, 158
- Single branch paralysis
 - facial paralysis, 363
- Sjögren's syndrome, 213
- Skin
 - envelope dissection, 274
 - facial fractures, 242
 - grafts
 - cheek reconstruction, 225–226
 - facial burns, 166
 - full-thickness, 14–15
 - physical models, 295
 - rhinoplasty, 274
- Skin care, 313–319
 - consultation, 315
 - pretreatment, 315
 - on-site clinic
 - benefits, 313–315
 - staffing, 313
 - preoperative program, 314
 - products, 317–319
 - treatments, 315–317
- SMAS. *See* Superficial muscular aponeurotic system (SMAS)
- Soft palate
 - sutures, 121
- Soft-tissue
 - cheek reconstruction, 205
 - defects
 - cognitive domain, 292
 - data assessment, 292
 - data processes, 282
 - imaging, 291–299
 - informational domain, 291–292
 - patient-specific three-dimensional models, 294
 - physical domain, 291
 - radiographic techniques, 294
 - simulation of surgical procedures, 295
 - three-dimensional distortion, 293
 - three-dimensional patient-specific data, 294
 - three-dimensional technologies, 295
 - tissue modeling, 292–294
 - mobilization
 - schematic diagram, 323
 - sarcoma
 - cheek reconstruction, 207
 - left cheek, 204
 - suspension, 322–323
- SOOF. *See* Suborbicularis oculi fat pad
- Spastic entropion
 - acute, 34
- Speech
 - instrumental assessment, 117
 - pathologist
 - relationship to surgeon in velopharyngeal dysfunction, 113–114
 - surgeon
 - terminology, 114–115
- Sphincter pharyngoplasty, 122
 - candidates, 122
 - complications, 124
 - long-term outcome, 124
 - operative technique, 122
 - postoperative care, 123
- Splints
 - nasal dorsum, 287
- Sporotrichosis*, 143
- Spreader grafts
 - rhinoplasty, 278
- Stickler's syndrome, 337
- Streptomyces somaliensis*, 135
- Submental flap
 - cheek reconstruction, 203, 228, 229
- Submental osteotomy, 357
- Suborbicularis oculi fat pad (SOOF), 323
 - lateral aspect, 328
 - suture, 329
- Subperiosteal facelift, 321–334
 - anatomic basis, 321
 - endoscopic, 325–334
 - indications for, 322
 - open approach, 321
- Sulfamylon cream
 - facial burns, 158
- Sulphur granules, 135
- Sunscreens, 317
- Supercilii muscle
 - transpalpebral incision, 97
- Superficial muscular aponeurotic system (SMAS), 186
- Supraclavicular flap
 - cheek reconstruction, 230–231

- Surgeon
 - relationship to speech pathologist in velopharyngeal dysfunction, 113–114
 - speech terminology, 114–115
- Surgical simulation techniques
 - VR programs, 298
- Sutures
 - endophthalmitis, 144
 - enhancing visualization, 121
 - placement
 - endoscopic midface procedure, 329
 - nasolabial crease, 367
 - primary cleft nasal repair, 303
 - removal, 144
 - soft palate, 121
 - transdomal, 280
- Symphysis, 351
 - anterior position, 352
- Symptomatic nasal airway obstruction, 277
- Tarsal strip technique
 - ectropion, 31–32
- Tattoo. *See* Traumatic tattoo
- Telangiectasia, 316
- Temporalis muscle injection
 - botulinum toxin A, 102
- Temporal trigger site
 - MH, 103
- Tensor-fascia lata flap, 64
- Tertiary facelift procedures, 322
- Thermoplastic material
 - facial burns, 163
- Thigh flap
 - anterolateral cheek reconstruction, 205–206
- Three-dimensional imaging advances
 - plastic surgery, 299
- Three-dimensional model of cartilage
 - congenital microtia, 295
- Three-dimensional model of skin
 - congenital microtia, 295
- Three-flap palatoplasty, 341
- Throat
 - facial fractures, 243
- Tip graft
 - middle crura, 281
- Tissue expansion
 - cheek reconstruction, 226
- Tissue modeling
 - soft-tissue defects, 292–294
- Tissue simulation
 - applications of surgical training, 296
 - background research, 296
 - plastic surgery, 297
- Titanium step-plate fixation
 - osteotomy, 355
- Tobramycin, 144
- Tonsillar pillar flaps, 123
- Topical burns
 - facial burns, 158
- Topical growth factors, 318
- Topical vitamin C, 318–319
- Trachoma, 134
- Transcutaneous lower eyelid retractor
 - repair, 33–34
- Transdomal sutures, 280
- Transition flaps
 - scars, 65
- Transpalpebral incision
 - supercilii muscle, 97
- Transpalpebral lateral retinacular suspension, 10
 - strengths, 10
 - weaknesses, 10
- Trapezius fascia
 - portion removal, 106
- Trapezius flap
 - cheek reconstruction, 230
- Traumatic tattoo, 193–198
 - acute debridement, 196
 - acute management, 198
 - chemical options, 196
 - chronic management, 198
 - common particles, 194
 - Fitzpatrick skin classes, 197
 - injury mechanisms, 194
 - laser energy, 197
 - management, 198
 - mechanical options, 196
 - methods, 193
 - pathophysiology, 194
 - photothermic, 197
 - pigment depth, 194
 - surgical options, 195
 - treatment options, 195–196
- Tretinoin, 317–318
 - peel, 316
- Triamcinolone
 - intralesional injections, 164
- Tricarboxylic acid, 316
- Trichloroacetic acid, 316
- Trichophytosis*, 143
- Trigeminal ganglio-rhizolysis
 - treatment of MH, 95
- Trigger sites
 - MH, 96, 99–100
 - temporal, 103
- Tumors
 - lacrimal sac, 139
 - resections, 298
- Turbinates
 - nasal cavity, 260
- Uebel technique
 - hair transplantation, 88
- ULC. *See* Upper lateral cartilage (ULC)
- Unilateral cleft deformity, 301
- Unilateral cleft lip
 - photograph, 306
- Unilateral cleft nasal deformity
 - illustration, 302, 304
 - photograph, 306
 - secondary repair, 304
- Unilateral facial paralysis reconstruction
 - photograph, 369
- Unilateral paralysis reconstruction
 - segmental gracilis muscle transplant, 371
- Upper blepharoplasty technique, 25–26
- Upper eyelids
 - blepharoplasty, 216
 - retraction, 34–35
- Upper lateral cartilage (ULC), 258, 284
 - cephalic trim, 283
 - fibrous ligaments, 259
 - nasal septum, 261
 - septum separation, 275

- Upper lip
 - cheek reconstruction, 188
 - ectropion facial burns, 173
 - reconstruction, 45
- Van der Woude's syndrome, 337
- Vascular circumflex scapular artery
 - perforator artery, 208
- Velocardiofacial syndrome, 337
- Velopharyngeal dysfunction (VPD)
 - airway evaluation, 116
 - anatomy, 114
 - basic speech terminology for the surgeon, 114–115
 - contraindications to surgery, 118
 - management, 113–126
 - managing, 117–118
 - nonsurgical options, 117
 - physical examination, 115–116
 - prosthesis, 117
 - provocative test, 116
 - relationship between speech pathologist and surgeon, 113–114
 - research
 - complex problems associated with, 125
 - surgical procedures, 119–120
 - treatment options, 117–118
- Velopharynx
 - birds eye view, 115
 - MRI, 126
 - nasoendoscopic view, 119
 - schematic representation, 114
- Vermilion
 - lip, 46–47
 - reconstruction, 47
- Vermilionectomy
 - vermillion reconstruction, 47
- Vertex skull defect, 347
 - CT scan, 348
- Virtual abdomen, 296
- Virtual reality (VR)
 - surgery applications, 298
 - surgical simulation techniques, 298
- Virtual-reality surgical-planning (VRSP), 297
- Visor flap
 - lip reconstruction, 52
- Vitamin C
 - topical, 318–319
- Von Langenbeck palatoplasty, 340
- VPD. *See* Velopharyngeal dysfunction
- VR. *See* Virtual reality
- VRSP. *See* Virtual-reality surgical-planning
- V-Y flaps
 - cheek reconstruction, 225
- V-Y pushback palatoplasty, 341
- War dill-Kilner-Veau technique, 341
- Webster cheek advancement flap, 50
- Webster modified Bernard-Burow cheiloplasty
 - lower lip reconstruction, 51
- Webster's triangle, 284
- Women hair loss, 78
- Wound contracture
 - facial burns, 165
- Wound healing
 - abnormal, 57–59
 - extrinsic factors, 56
 - intrinsic factors, 56
 - normal, 56–57
 - scanning electron microscopy, 57
- W-plasty
 - scars, 63
- Xylocaine
 - MH, 104
- Z-plasty
 - facial burns, 166
 - rearrangement, 63
 - scars, 62
- ZTBTN. *See* Zygomaticotemporal branch of the trigeminal nerve
- Zygoma
 - reduction, 249–250
- Zygomatic arch
 - illustration, 324
 - periosteum elevation, 324
- Zygomatico buccal branches, 359
- Zygomaticotemporal branch of the trigeminal nerve (ZTBTN), 96
 - detachment, 97
- Zygomaticus major, 360
- Zygomaticus minor, 360

Plastic Surgery

about the book...

Whether from trauma, congenital deformity, or disease, many patients can present with disfiguring and debilitating facial defects. This reference presents a range of expertise on soft-tissue surgery of the craniofacial region for improved function and enhanced cosmetic appearance. Covering the latest technologies available, this source includes chapters on laser imaging, burns, cleft palate, and facial paralysis.

Highlighting the current practice and management of anomalies and abnormalities within soft tissue surgery of the craniofacial region, this text will inspire the reader to develop stronger solutions to the persistent problems encountered in craniofacial surgery. Essential topics covered include... the analysis and surgical treatment of soft tissue deformities of the craniofacial skeleton...new advances and techniques in tissue expansion and microvascular transfer of soft tissue...the sophistication of aesthetic techniques amenable to reconstructive surgical problems, such as nasal reconstruction following cancer, ear reconstruction for congenital anomalies, and lip reconstruction following tumor ablation...irregularities in the face and neck, with both issues being highlighted individually within the text.

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Printed in the United States of America

informa
healthcare

www.informahealthcare.com

52 Vanderbilt Avenue
New York, NY 10017
Telephone House
69-77 Paul Street
London EC2A 4LQ, UK

DK3574

ISBN 978-082472893-9



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